MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

William John Greenstreet, M.A. (Camb.), Marling School, Stroud, Gloucestershire,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

William Ambrose Kibbler, M.B., Ashby House, 3 Manor Road, Stamford Hill, N. (proposed by the Rev. T. E. R. Phillips) ;

C. F. Sandberg, M.A. Oxon., Magdalen College School, and 6 Parks Road, Oxford (proposed by H. C. Plummer) ;

Albert Walter, Royal Alfred Observatory, Mauritius (proposed by E. W. Maunder) ; and

Edward Fawcett White, Navigation Department, Merchant Venturers' Technical College, Bristol (proposed by Captain P. Thompson).

Eighty presents were announced as having been received since the last meeting, including amongst others :—S. Newcomb, "The Stars, a Study of the Universe" (presented by the publishers).

Contribution to the History of the Reflex Zenith-Tube.

By S. C. Chandler, Assoc. R.A.S.

(*Communicated by the Astronomer Royal.*)

It may not be uninteresting to the Society to lay before them the following note concerning an instrument, notable in English astronomy, whose history has passed through various phases—in the beginning of high hope, later of grievous perplexity, finally of severe disappointment. Mr. Adams, in 1852, concluded his address of presentation of the medal to Mr. Peters with the following words : " We may hope that the beautiful reflex zenith telescope of the Astronomer Royal . . . will enable us ere long to take many firm, though long-reaching, steps into regions of space hitherto untrodden." Subsequently, however, the successive discussions of Main and Downing gave unacceptable results, as is well known, and in 1882 the observations were silently abandoned.

In the *Astronomical Journal*, No. 511, it is shown that this instrument, so far from being a failure, has provided us with an invaluable record of a phenomenon which was unsuspected at the time the observations were made, and which has within the last decade become the subject of the most active and general inquiry ; namely, the relative motions of the earth's axes of rotation and figure. There is one topic, not there touched upon, on which a few words here may not be superfluous. The object of this note is to expose directly and analytically how the anomalous parallax of γ *Draconis* and aberration were brought about.

In *Astronomical Journal*, vol. xii., p. 177, it is shown that the coefficients of the sine and cosine of the Sun's longitude,

$$Y = qu - p\pi + \eta, \quad Z = pu + q\pi + \zeta \quad . \quad . \quad (A)$$

are functions of four unknown quantities; namely, the parallax π, the correction u of the assumed aberration-constant, and the coordinates of the annual component of the motion of the pole,

$$\eta = -r_2 \sin G', \quad \zeta = -r_2 \cos G'$$

r_2 and G' being furnished by observation, and the coefficients

$$p = \sin \varepsilon \cos \delta - \cos \epsilon \sin \alpha \sin \delta, \quad q = \cos \alpha \sin \delta$$

from known quantities. For γ *Draconis* we have (1865) $p = +0{\cdot}965$, $q = -0{\cdot}022$. From *Astronomical Journal*, No. 511, p. 59, we take :

	1857-63.	1864-70.
r_2	0″·166	0″·134
G'	323°	313°

consequently η $+0''\cdot100$ $+0''\cdot098$
„ ζ $-0''\cdot133$ $-0''\cdot091$

which are the values of Y and Z if u and π are zero. If, on the contrary, we ignore η and ζ, as was in effect done in the earlier attempts to get aberration and parallax, we have from (A)

$$u = \frac{q\mathrm{Y}+p\mathrm{Z}}{p^2+q^2}, \quad \pi = \frac{q\mathrm{Z}-p\mathrm{Y}}{p^2+q^2}$$

which would give, introducing the above data and the assumed aberration $20''\cdot505$,

	Aberration.	Parallax.
	$''$	$''$
1857–63	20·365	−0·100
1864–70	20·408	−0·099
Mean . .	20·386	−0·100

The values actually found by Downing, from the observations 1857–75, were

$20''\cdot378$ $-0''\cdot131$

thus a satisfactory agreement with the foregoing, the differences being nominal and doubtless due to the fact that he included the observations for 1871–75, which I did not.

The above demonstration, while possibly unnecessary, is not uninteresting as showing explicitly how the former anomalous results are harmonised with the truth as now perceived. The old discussions are practically attempts to find four unknowns from two equations.

It is certainly a comfort that the perplexing enigma connected with the Reflex Zenith-Tube has finally found its answer, and that the patience of the astronomers who executed this laborious series meets at last an adequate reward of useful result. The question naturally arises in the mind whether a resumption of observations by this method, with an instrument optically capable of more easily showing γ *Draconis* in the daytime, and an earnest attention to securing a higher precision as regards accidental error of observation, would not be a worthy undertaking.

If such a resumption of the investigation under these more favourable conditions be feasible, it scarcely needs to be suggested that it ought properly to extend to all the stars passing the Greenwich zenith bright enough for reflection-observation on a dark sky. This would determine both the aberration and the latitude-variation, which is not possible with a single star. At least two groups of stars in opposite right ascension would be desirable. Assuming the limit of brightness to be $6\frac{1}{2}$ magnitude, a list of all the stars that might be embraced in such a programme is appended.

No.	Mag.	(1905·0) α h m s	δ ° ′	
1	6·0	0 19 8	+51 29·6	—
2	6·1	1 44 52	28·0	—
3	6·6	1 58 0	30·7	—
4	5·4	4 59 14	28·4	Fl. 9 Aurigæ.
5	6·6	5 39 29	29·0	—
6	6·5	5 43 23	29·2	—
7	6·6	7 26 33	31·1	—
8	6·8	10 24 18	28·8	—
9	6·0	13 59 28	25·7	—
10	2·5	17 54 24	30·0	γ Draconis.
11	6·8	18 59 59	29·6	—
12	4·0	19 27 19	31·5	ι Cygni.
13	6·4	20 32 4	31·6	—

On the Velocity of a Persei. By H. F. Newall.

The following additional observations of the velocity of *a Persei* in the line of sight were obtained before I left England to observe the eclipse of the Sun in Sumatra. They are in continuation of the observations published in an earlier note (*Monthly Notices*, vol. lxi., p. 12), and were obtained with the same instrument and measured in the same way as those before published. The values of the velocity are the means of two measurements made, one by myself, the other by my assistant, A. W. Goatcher. The result for each photograph is based on measurement of about eleven lines between λ 4260 and λ 4325, and the method of reduction is the same as that briefly described in a paper published in *Monthly Notices*, vol. lxi., p. 12.

Velocity of a Persei in the Line of Sight.

Plate Number.		Velocity relative to Earth.	Correction for Earth's Orbital velocity.	Velocity relative to Sun.
F. 139	1900 Nov. 9·35	− 2·7	+ 5·8	+3·1
F. 141	10·35	− 4·4	+ 5·4	+1·0
F. 142	13·34	− 3·7	+ 4·1	+0·4
F. 143	15·33	− 4·0	+ 3·2	−0·8
F. 145	16·33	− 6·7	+ 2·7	−4·0
F. 154	Dec. 10·25	+ 7·0	− 8·1	−1·1

Plate Number.			Velocity relative to Earth.	Correction for Earth's Orbital velocity.	Velocity relative to Sun.
F. 155		13·25	+ 7·3	− 9·4	−2·1
F. 159		17·24	+13·7	−11·0	+2·6
F. 160		19·25	+12·5	−11·9	+0·6
F. 162		21·23	+12·0	−12·7	−0·7
F. 180	1901 Feb.	12·39	+25·9	−25·8	+0·1
F. 181		13·40	+24·5	−25·9	−1·4

These results were very nearly ready for publication in February last, but the appearance of the new star in *Perseus*, and stress in connection with preparations for the eclipse expedition, which started from England on March 11, stood in the way of the necessary completion of the discussion, and to my regret it was left unfinished. Meanwhile, Professor Vogel and Professor Campbell kindly responded with great promptness to the expression that I gave in my previous note to the hope that observations of the star would be secured at other observatories ; and I would here express my obligations to them. Their published results (*Sitzber. Berlin Akad.* 1901, p. 51, and *Lick Obs. Bull.* No. 4) show that no support is found either at Potsdam or at the Lick Observatory for my suggestion that the velocity varies periodically.

My later observations given above showed at once that they would not fit either of the periods, 4·2 days or 16·8 days, which I had suggested as possible.

As Professor Vogel has pointed out, I have used a linear dispersion about two and a half times that obtained in the instrument he has used for making his observations at Potsdam ; it is about twice as great as that used by Professor Campbell.

While it is clear that the larger dispersion might bring to light changes that were not detected on photographs of smaller scale, it is also evident that the use of it would be attended with greater risks arising from temperature changes, &c. Every precaution has been taken to avoid risks of this kind, short of putting in an arrangement for generating heat inside the non-conducting covering which surrounds the spectroscope. The photographs were obtained with all care and afford apparently excellent material for the measurements to be made. The spectrum of *α Persei* is admirably adapted for an accurate investigation ; for the lines are numerous and distinct, and in spite of an exhaustive study of the material I have at present no clue as to the cause of the discrepancies.

On a Simple Method of Accurate Surveying with an Ordinary Camera. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. Measurements of photographs have proved so accurate and convenient in astronomy that they will probably be found useful elsewhere. The present paper suggests an extension of the methods adopted for treatment of the Astrographic Chart plates to terrestrial surveying ; and although not definitely astronomical, since it arises out of astronomical work, it may perhaps not unsuitably be communicated to this Society.

2. *Uses of the camera in surveying hitherto.*—Instruments designed for using the camera in terrestrial surveys have hitherto started with the theodolite as a substructure. Now the theodolite is primarily designed to measure *angles*, and I hope to show in the present paper that the use of angles is unnecessary, and only complicates the formulæ. It is not an angle itself but the tangent of an angle which arises fundamentally in the work, when a view of any kind is projected on a plane ; and if we keep to plane geometry with straight lines and linear formulæ, we get much simpler formulæ ; just as in astronomical work it simplifies matters to use rectilinear coordinates instead of curvilinear or angular. This has not been realised (so far as I have been able to find out) in surveying any more than it was in astronomy ; indeed existing instruments for photographic surveying often contain a "scale of tangents" designed to enable the surveyor to convert the convenient linear measures with which the photograph directly furnishes him into angular measures, which are really more inconvenient but to which he has become accustomed from use of the theodolite.

When the photographs have been obtained methods of making use of them have usually been graphical ; and the positions of points have been laid down by the "method of intersections." Now graphical methods are limited by practical considerations, such as size of paper ; and though in many cases they may be all that is necessary, it is convenient to have a more complete method. In the present paper it is shown how accurate measurements of the plate can be used, without any troublesome calculations, to give all the required data. Thus we may state the

3. *Advantages of the present method* under two heads : (*a*) the use of linear measures and formulæ entirely, instead of angles, and (*b*) the substitution of accurate measurement of the plate for graphical methods of treating the photographs. Under head (*a*) is to be ranged the considerable practical gain of doing away with any complicated or expensive mounting, and using a camera of the ordinary pattern.

4. *Principle of the method.*—Let A be the centre of a lens forming an image on a plate GE, and let the image of a point

P fall at G. We shall suppose for the present that there is no optical distortion, *i.e.* that the images on the plate all fall truly on rays through the point A ; and the way of dealing with any deviation from this law will be considered later.

Let AE be drawn normal to the plate from the centre A. The point E, which is the foot of the normal from the lens centre on the plate, is of some importance and will be called the plate centre. Let AE=f. It is the focal length of the lens when an infinitely distant object is in focus, and in all cases is of comparable dimensions with this focal length.

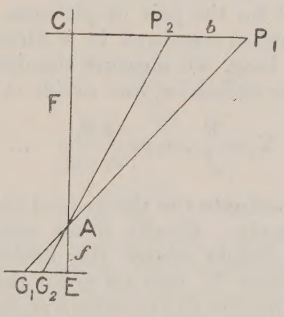


FIG. 1.

The coordinates of P in space referred to axes AC, CP are

$$AC=F \text{ say, and } CP=X$$

and if we put EG, the measured distance of the image from the plate centre, equal to x, we have of course

$$x/f=X/F \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

From measurements on a single photograph we can get nothing more than this—the ratio X/F. To determine either of these completely we must take another photograph. Now it will clearly be of advantage to keep one or other of these quantities the same in both pictures. If we keep F the same we must move along a line parallel to the plate ; if X the same, along a line perpendicular to the plate. Both these plans have special advantages, and we will consider them each in turn.

5. *The parallactic or stereoscopic method.*—Let us move the camera a measured distance b to the right, keeping it parallel to itself. (The practical method of securing these conditions will be considered presently.) Then this is equivalent to supposing all the objects in the field of view moved a distance b to the left

as in fig. 1. Denote the first and second positions by the suffixes 1 and 2 ; so that we have

$$\left.\begin{aligned} x_1/f &= X_1/F \\ x_2/f &= X_2/F \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

and $X_1 - X_2 = b$

whence $(x_1 - x_2)/f = b/F$ ... ... (3)

or $$F = \frac{bf}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Now bf is a constant for the pair of pictures. Thus to get the distance F of any object measured in a direction perpendicular to the plate, or the base, we measure the distances x_1 x_2 on the two plates, take their difference, and divide it into a constant.

Again $$X_1 = \frac{F}{f} \cdot x_1 = \frac{b\,x_1}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

so that the other coordinate (on the ground plan) of the object is obtained equally simply. Finally if we want the elevation of the object, call its height above the horizontal plane AGE through the lens centre Y, and let y be the measured height of the image above the line EG on either picture. Then clearly

$$Y = \frac{F}{f} \cdot y = \frac{b\,y}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

Thus the actual coordinates XYF of the object in space are obtained from the measures on the plate x, y, and the focal length f on multiplying by the factor $b/(x_1 - x_2)$. But since this may also be written in the form F/f and is constant, it follows (as might have been expected) that we can increase $x_1 - x_2$ to any desired extent by increasing b.

6. *Convenient size of base.*—A few figures may be given at once to show the kind of base that will give good results. Suppose f (the focal length of the camera) to be 1 foot, and let b be 100 feet. This is a comparatively modest base, which would generally be available by selecting positions with care. Then if $x_1 - x_2$ be a quarter of an inch, or 0·021 feet,

$$F = 100/0{\cdot}021 = 4{,}800 \text{ feet, or nearly 1 mile.}$$

Now, how accurately can we measure the difference $x_1 - x_2$ and thus determine the distance of objects a mile away ? Experience has shown that it is easy to measure a photograph within, say, a thousandth of an inch—no one will think this too severe a limit. It corresponds to 1″·5 on the astrographic plates, and most observers would concede a division by at least 10. But we must remember that terrestrial objects may not be as well defined as stars, and so we will take an outside limit, say 0·001 inch. This

would correspond to an error of 1/250 of the distance at a mile away, say 20 feet; and this is considerable accuracy. For other distances the error is as the square of the distance, *e.g.* at 5 miles it would be 500 feet.

7. *Second method. Advance in direction of view.*—The formulæ, when we keep X the same, are equally simple. We have

$$\left.\begin{aligned} f/x_1 &= F_1/X \\ f/x_2 &= F_2/X \\ F_1 - F_2 &= b, \text{ say} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (7)$$

Thus $$f\left(\frac{1}{x_1}-\frac{1}{x_2}\right)=b/X$$

or $$\left.\begin{aligned} X &= \frac{b\,x_1x_2}{f(x_2-x_1)} \\ F_1 &= \frac{bx_2}{x_2-x_1} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (8)$$

and obviously $$Y_1=\frac{F_1}{f}y_1$$

The weak point in this case is that when $x_1=0$ we have $x_2-x_1=0$: that is, the method fails to give results for objects near the middle of the picture. There is, however, a corresponding advantage in the adjustments of the instrument, as will presently appear.

8. *Necessary conditions.*—It remains to consider how to secure the necessary conditions, which are:

(1) To measure a base of a given length in a given direction. The practical difficulties here are such as need not concern us.

(2) To keep the camera parallel to itself. For this the camera should first be fitted with at least two cross levels. No reversal of the levels is necessary, as it is only necessary that the camera should be parallel to itself; but if the levels have serious errors, the survey will not be referred to a true horizontal plane. The levels will check the parallelism so far as rotations about horizontal axes are concerned. As regards that about a vertical axis,

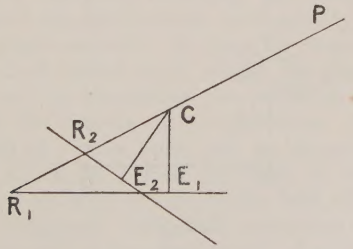


FIG. 2.

remark that in the second method this adjustment is checked by the pictures themselves, for objects at the middle of the picture

should not be displaced at all ; and any displacement at once shows lack of parallelism. There is no difficulty in applying the correction for lack of parallelism, which takes a form already familiar in astronomical work. Let C be the centre of the lens, E_1R_1, E_2R_2, the correct and displaced positions of the plate ; P an object which forms images at R_1, R_2.

Then
$$\left.\begin{aligned} E_1R_1 &= f\tan\theta \\ E_2R_2 &= f\tan(\theta-\alpha) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where α is the angle of displacement and may be supposed small.

Hence
$$E_2R_2 = f\tan\theta - f\alpha\sec^2\theta$$

or
$$E_2R_2 - E_1R_1 = -f\alpha\left[1+\left(\frac{E_1R_1}{f}\right)^2\right] \quad . \quad . \quad . \quad (10)$$

Thus the displacement of an object near the middle of the plate is nearly constant and measures the constant $f\alpha$ with accuracy. And for other objects we multiply this correction by a simple factor.

9. For the first or stereoscopic method the determination of this fundamental adjustment is not quite so simple, as all the objects in the picture are shifted. A compass-needle on the camera would not give the parallelism with sufficient accuracy when the base is small. If there is one object in the picture whose distance is accurately known, the error of parallelism could be found ; but if the object is near, a considerable accuracy in its distance is necessary. The best general methods of securing this parallelism would probably be found only by experience ; but that there is no essential difficulty may be seen from the following suggestions.

(*a*) If a cross telescope were attached to the camera it could be pointed on a distant object, the same in each position ; or,

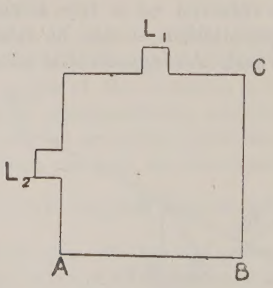


FIG. 3.

better still, two objects in line, such as two staffs set up for the purpose.

(*b*) Suppose a camera fitted with two lenses in two adjacent

faces ; L_1 giving a picture on a plate AB, and L_2 on a plate BC. Let both pictures be taken without moving the camera. Then advance 100 feet, either in the direction BC or BA, and take another pair of pictures. If in the direction BC, then the pair with lens L_1 will give an accurate measure of the error of parallelism, which can be used to reduce the pair of stereoscopic pictures taken with L_2. It should be remarked that fig. 3 is only the ground plan of the cameras, which can be separate instruments firmly attached together with lenses at right angles. The image formed by one lens could be reflected by a diagonal reflector on to the same plate as that formed by the other.

(*c*) If only one camera is available it can be made to serve as a pair at right angles, even without any accurate instrument for measuring angles. Nail two laths with straight edges at right angles to one another on a board, and place some fiducial edge of the camera against each in turn, taking care not to move the board between the exposures. There should be no real difficulty in securing this adjustment even in field work.

10. *Form of camera.*—It will be seen that no special form of camera is necessary, and probably the most convenient will be the simplest : a rectangular box with no focal adjustment, or better, two such firmly attached at right angles, would give good results. Either films or plates might be used, but if films, then a plate of réseau lines should be fixed immediately in front of the film. In any case there should be at least one set of cross-wires to identify the origin for measures on the two plates.

11. *Optical distortion* need not be a trouble even though it be large, as may happen with a wide-angle camera. It should be *determined* thus : expose the camera to any view first with the aperture which is to be used in practice ; secondly with a pinhole stop : measures of the two pictures will at once give the correction for distortion at different distances from the optical centre.

12. *The measures* should be made by the method of rectangular coordinates, in any of the ways found convenient for star measures. A series of réseau lines impressed on the plate is almost a practical necessity, but there is no need to dwell on points of this kind which have already been worked out in the case of star-measures. It may be remarked incidentally that a good deal of useful work might be done without taking photographs at all, by measuring the positions of images on the ground glass of the camera, or a substitute. If the substitute be a photograph of réseau lines, and an eyepiece with a cross-scale attached to it be placed carefully in contact with this photograph, so as to focus objects in the field of view, the réseau lines, and the cross-scale altogether, measures of position could be made at once, and a few such would doubtless be a valuable check on the photographic measures.

13. *General plan of survey.*—The following general plan of operations may thus be suggested. On any route, however

irregular, there will be opportunities for selecting pairs of stations accurately in the line of march, and 100 feet apart (or some other convenient distance). By pairs of photographs taken as above the positions of near objects can be determined well, and those of distant objects not so well. But these latter will appear on many photographs, and we thus get longer bases from which to determine them more accurately. A compass needle attached to the camera, though useless for avoiding minute differences of orientation, would be very useful in comparing results at distant stations.

On the Accuracy of Measures on Photographs: Remarks on recent Papers by M. Loewy and Mr. H. C. Plummer. By Arthur R. Hinks, M.A.

In the supplementary number of the *Monthly Notices*, 1901 (vol. lxi., p. 618), Mr. H. C. Plummer has recently discussed the very elaborate memoir by M. Loewy, "Sur la précision des mesures des coordonnées rectilignes des images stellaires," in the eighth circular of the *Conférence astrophotographique internationale de Juillet* 1900. M. Loewy has sought to find a general formula which shall give the probable error of the mean of a number of settings upon a star image, in a number of different orientations of the plate; and concludes that to avoid systematic error it is necessary to measure the plate in four orientations. Mr. Plummer has rediscussed the figures which M. Loewy gives, and comes to a number of conclusions, of which the most important are:

"(4) By combining measures made in the direct and reversed positions of the plate a much better result is obtained, to which M. Loewy's formula does *not* apply.

"(6) The error eliminated by reversing the plate is definite for each image, but may vary both in magnitude and in sign from one star to another."

Briefly, the principal point in dispute is, Can a sensible compensation of the systematic errors of measurement be obtained by measuring the plate in two positions whose orientations differ by 180°?

My excuse for intruding into the discussion between M. Loewy and Mr. Plummer at this point is as follows: For some months I have had the pleasure of being in correspondence with M. Loewy in reference to certain aspects of the question; he has been so kind as to give me very full and interesting explanations of his views; and I have his permission to give some passages from his letters in the present note.

At the beginning of his memoir (*loc. cit.*) M. Loewy says:

"Il y a donc à distinguer, lorsqu'on détermine une co-

ordonnée rectiligne, deux catégories d'erreurs : l'une, l'erreur accidentelle E_a, et l'autre, E_s, l'erreur systématique. . . . L'erreur totale E_t se trouve donc exprimée par la formule

$$E_t = \sqrt{E_a^2 + E_s^2}. \text{ "}$$

Now it is evident at once, as Mr. Plummer has pointed out, that the expression "systematic" error is not used here in its ordinary sense ; truly systematic errors of course do not follow the law of distribution which is the basis of the method of least squares. And to destroy the validity of the above equation it would be necessary to show only that the distribution of error in photographic measures is not entirely accidental ; that it tends to be of opposite sign in opposite orientations of the plate for example.

On this point M. Loewy writes (1901 October 16) :

"Je saisis cette occasion de préciser d'avantage la principe qui m'a guidé dans l'établissement des formules.

"Une fois la moyenne d'une série de pointés formée, ce résultat est affecté de deux catégories d'incertitudes, l'une a pour expression E_a/n" [apparently a slip for $E_a/\sqrt{n}$] "et l'autre est représentée par E_s.

"E_s est une erreur accidentelle d'une autre espèce affectant la moyenne. . . .

"Or, les expériences ont montré que, lorsqu'on répète les mesures dans une même orientation, avec un même observateur, après plusieurs mois d'intervalle, E_s varie notablement. Pour ce motif, on préfère ne répéter une seconde fois la détermination des coordonnées rectilignes que plusieurs mois après l'exécution de la première série de mesures. . . . Il n'est permis ici de faire aucune supposition sur une loi quelconque qui relie entre elles les différents valeurs de E_s, soit en signe, soit en grandeur. E_s est évidemment à considérer comme une erreur accidentelle d'un autre genre.

"Comme il convient, d'un côté, d'attribuer le maximum d'effet aux sources d'erreurs, et qu'il fallait d'un autre côté embrasser la généralité des cas, j'ai dû admettre qu'il n'existe aucun lien entre les E_s relatives, aussi bien à différents observateurs qu'à diverses orientations, même si celles-ci diffèrent de 180°—ayant fait d'ailleurs, comme je l'ai dit dans ma dernière lettre, des expériences qui confirment cette dernière hypothèse."

These experiments are thus described in a former letter (1901 September 12) :

"On a généralement admis, ainsi qu'à Paris, que cette petite anomalie constante dans une orientation donnée, s'élimine dans la moyenne de deux séries de mesures faites dans des orientations différant de 180°. Comme cela a été expressément répété dans plusieurs endroits de ma note, on ne peut admettre *a priori* aucune hypothèse, quelque soit son degré de probabilité, lorsqu'il s'agit d'atteindre le dernier degré de précision.

"Nous avons fait sur cette question de nombreuses expériences, avec divers appareils, et dans des conditions variées, et j'ai reconnu que dans le plus grand nombre des cas cette supposition est absolument inadmissible. On arrive *à peine* à une compensation partielle d'erreurs que dans des cas exceptionnels. . . .

"Dans le cliché que nous avons examiné, grace à ces qualités, il s'est produit dans les nombres relatifs aux positions différant de 180° quelques compensations ; mais elles sont de peu d'importance, en regard de la somme totale des résidus. En effet en formant d'abord deux à deux la moyenne des résidus entre les positions différant de 180°, et calculant après l'erreur probable, on trouve une valeur à peine différente d'un centième de seconde d'arc de celle figurant dans ma note."

To sum up briefly M. Loewy's view, it is necessary to consider "l'erreur systématique" as an accidental error of another kind, that is to say, differing from the accidental error deduced from the divergence of successive pointings in a single orientation, because, in the first place, experiments have shown that the systematic error is certainly not really systematic, but varies from time to time, and secondly because a rediscussion of the observations on the supposition that there may be some compensation when the plate is reversed leads to the original result. Now this is in absolute contradiction to the result which Mr. Plummer deduced from the same figures. And the discrepancy is of the highest importance because the validity of M. Loewy's fundamental equation turns upon it. If the "accidental error of another kind" can be shown to be not really accidental, if the errors in the measures of a given image in a given orientation of the plate are not equally likely to be positive or negative, then E_s is not an error which comes within the operation of the ordinary theory of errors, and the whole of M. Loewy's theory which follows on his fundamental assumption breaks down.

In a case such as this, where the validity of the application of the method of least squares is in dispute, there is at any rate a formal advantage in examining it from a point of view which does not involve the deduction for after-comparison of probable errors by the usual laws. I have therefore examined a part of M. Loewy's figures as follows.

His plate has a triple exposure, and 82 triple images were measured by two observers, A and B, in four orientations. Both M. Loewy and Mr. Plummer have treated the means for the three exposures as one complete measure. There is, however, a certain advantage in considering the exposures separately. Again, both have discussed the residuals of each setting from the mean of all for the two observers. Apart from the question which Mr. Plummer raises whether the two observers are equally skilled, there is a curious discontinuity in the results for B that leads to the suspicion that parts of certain columns of his figures have been interchanged. I fully agree with Mr. Plummer that this discontinuity is manifest—it appears in the measures for the

separate exposures, as well as in the mean for the three ; and I propose therefore to discuss only the measures of observer A.

In Tables VI. 1 and VI. 2 of M. Loewy's paper we find the individual measures made upon the first and second images of each of the 82 stars, in four orientations, 0°, 90°, 180°, and 270°. Forming afresh the means for observer A only, we obtain from his measures 656 residuals. The point to be determined is whether these tend to be of opposite signs in opposite orientations. We will consider separately the pairs of opposite orientations 0° and 180°, 90° and 270°, and divide each series into two classes—I., in which the residuals in opposite orientations are of the same sign ; II., in which they are of different signs. If the residuals are distributed impartially, both as to sign and magnitude, these two classes will be equal. We will further subdivide each class according to the magnitude of the sums of the pairs of residuals, without regard to sign. Again, if the residuals are distributed impartially, large numerical sums will occur with equal frequency in each group.

The results of this analysis are as follows :

Classification of Numerical Sums of Residuals in Opposite Orientations.

Exposure 1.	0° and 180°. I. Same Signs.	0° and 180°. II. Opposite Signs.	90° and 270°. I. Same Signs.	90° and 270°. II. Opposite Signs.
Sums between 0 and 19	13	7	7	9
20 „ 39	7	16	8	24
40 „ 59	8	12	9	13
60 „ 79	2	7	2	5
80 „ 99	1	3	1	2
100 and over	0	6	0	2
	31	51	27	55
Exposure 2.				
Sums between 0 and 19	13½	9½	14½	9½
20 „ 39	13½	18½	15	13
40 „ 59	3	6	3	14
60 „ 79	0	7	0	9
80 „ 99	0	4	0	2
100 and over	1	6	1	1
	31	51	33½	48½

The halves appear because in some cases one residual is zero, and the pair has to be divided between groups I. and II.

These numbers give abundant support to two conclusions :

(1) That in pairs of opposite orientations the residuals are more frequently of opposite sign than of the same sign.

(2) That when the residuals are large, and their numerical sum correspondingly large, they are almost always of opposite sign.

It seems to me, then, that these residuals cannot be treated as accidental in any sense whatever; that they do not come under the operation of the ordinary law of accidental errors at all; and that consequently M. Loewy's fundamental equation is not valid. I do not therefore find myself in agreement with Mr. Plummer when he says: "We may follow M. Loewy in denoting the accidental and systematic errors by E_a and E_s respectively, and the total probable error by E_t, and admit that $E_t^2 = E_a^2 + E_s^2$." This is indeed in obvious contradiction to his conclusion that there is a striking compensation of errors when the plate is measured in reversed positions—a conclusion which is entirely supported by the figures given above.

One can scarcely avoid coming to the conclusion that it will be wise to hesitate before committing oneself to the arduous programme which M. Loewy recommends; and this view is supported by the circumstance that there is another category of error, of which he has not up to the present time taken any account, the real error of position of the star image on the plate, due to such causes as irregularity in the size or distribution of the particles of silver in the image, or local shrinkage of the gelatine film which is not eliminated by the use of the réseau. It is not possible to discuss the magnitude of this source of error on M. Loewy's plates, because he has given the measures of one coordinate only, and one cannot discover whether there has perhaps been a slight change of orientation, &c., in the interval between the exposures which would affect the differences between the coordinates with an error which is a linear function of those coordinates. It has, however, been abundantly proved that this third category of error may exist; it is not possible to deduce an estimate of the real accuracy of the resulting positions of the star from an examination of the discrepancies between the measures on a single exposure, or set of exposures treated as one, however carefully the conditions of measurement may be varied. The ultimate test is the agreement between the results of two separate exposures when one is rigidly reduced to be comparable with the other, if necessary. And it should be noted that a really systematic error in measurement, if such exists, unchanged from star to star, is of no moment, because it is eliminated by the process of finding from known stars the correction to the plate centering.

It seems to me, then, that the following process gives an estimate of the probable error of a complete measure which is a trustworthy guide to the real accuracy with which relative star places can be obtained from a photograph. Take two exposures immediately following one another: measure them, and examine (1) whether the differences between the measured coordinates of the two exposures depend upon the position of the star upon the plate; (2) whether they vary with the magnitude of the star, as they may possibly do if the guiding is not perfect. If they pass this examination, the divergences of the differences from the

mean will be a criterion of the inaccuracy which arises from all those categories of error, accidental error of setting, systematic error of measurement due to personality or otherwise, and systematic error of position of image due to irregularity or local defects. It is, then, of no consequence to examine elaborately the divergences from the mean of settings on a single exposure.

Cambridge Observatory:
1901 *December* 12.

The Spectrum of Nova Persei from 1901 *February* 28 *to April* 26. *With Appendix on the Spectrum in September.* Rev. W. Sidgreaves, S.J., Stonyhurst College Observatory.

Introduction.

In "Notes on the Spectrum of *Nova Persei*," presented at the March meeting of the Society, it was briefly stated that the notes referred chiefly to photographs obtained with an objective prism of 4 inches aperture mounted on the finder of the large equatorial. It is necessary to preface the present paper by a more detailed description of this prismatic camera, on account of the difficulties which had to be overcome in order to secure accurate settings of the spectrum on the photographic plate. The importance of this adjustment is many times greater when the object-glass is corrected only for the visual rays than when a correcting lens for the photographic rays is employed, on account of the steep inclination of the plate to the optic axis of the lens, required for the simultaneous focus of the several photographic rays.

The camera is provided with a rotating frame for carrying the dark slide, and a graduated circle for setting the angle of inclination required. Another slide of the same dimensions as the dark slide carries three platinoid wires drawn taut over screw-heads—a pair of parallel wires, and one at right angles to the pair. When this slide is in the camera the wires lie in the plane to be occupied by the photographic plate. Its structure is simple, consisting of a plate of hard wood, with a central hole over which the wires are drawn, and side rails bringing up the sliding thickness to that of the dark slide. The space between the rails is left open at the ends to admit the light of a taper to illuminate the wires.

When the star is in the field its spectrum is seen with an eyepiece at the back of the camera as a sharp colour line, red at one end and blue at the other, together with the wires. The camera is set in position with reference to the prism by turning it in its adapter to bring the pair of lines parallel to the colour line image of the star; and the spectrum is brought into position on the

plate by setting it between the parallel wires, with the cross wire cutting out the yellow part of the spectrum. In this operation the eye has to be satisfied that there is no bluish-green on the red side, and no orange-yellow on the violet side of the cross line. This cross wire or bar is fixed not centrally in the field, but considerably to the side of the less refraction of the prism, in order to keep the photographic spectrum nearer the centre of the plate.

The length of the spectrum is 21 mm. from Hβ to Hν. About one-fifth of this is by the secondary spectrum of the object-glass, brought into service by the inclination of the plate.

With this inclination at 36°·5, Hβ and the region at and beyond Hϵ can be brought into simultaneous focus, and a shorter focus of about a millimetre brings the intervening region to the best definition. The latter adjustment has been employed on every date except February 28, when an error was made with the focus rack. The former was employed only on March 3, 12, and 16. The difference between the two focal lengths is not too great to hinder a compromise between them; and this has resulted occasionally from imperfect settings when the light of the star was too weak, or that of the sky too strong for seeing easily the yellow part of the spectrum.

The tube of the telescope is mounted so as to turn easily on its axis. This is a convenience for an adjustment to compensate for changing refraction, when the star is low and away from the meridian; and by it the slant of the spectral lines of the *Nova* has been greatly diminished, but only fully corrected on the later exposures.

The succession of fine nights in the earlier part of February came to an end on the 20th, just before the new star made its appearance. It was followed by a week of unbroken cloud until 10.30 P.M. of the 28th; and since then no opportunity has been lost of observing the spectrum of the star, in order to collect all information possible about the subsequent changes in its structure, which had been very great and very rapid in the early days of its life.

It was during the preceding fine week that the experimental work for selecting the angle of inclination of the plate and finding the focal adjustments had been completed for the ordinary photographic rays; but nothing had been done for an orthochromatic plate. And since the inclination of the plate for the green and yellow rays would have to be practically nothing, it was decided to make no attempt on these with the prismatic camera, but to leave them to the direct compound prism attached to the greater telescope; and thus the angle of inclination, on which all measurements in the spectra so much depend, has not been altered since its final selection. But only one isochromatic plate (Edwards) has been employed on the *Nova*, viz. on February 28, while the star was bright enough to give its green spectrum, to which the plate is only feebly sensitive.

Discussion of the Spectrographs.

1. *The continuous spectrum* of the star is remarkable for its great relative strength in the ultra-violet region. Compared with other stars, whether of the white or yellow type, the density of the silver deposit in the region near and beyond the head of the hydrogen series should be accompanied by a density in the blue region, at least equal to the darkest parts of the negative between Hβ and Hγ. It was, therefore, at the beginning, a question between two opposing interpretations of the spectrum : Whether it was to be called a strong, continuous spectrum crossed by broad absorption bands and the bright hydrogen series, or a weak continuous spectrum with bright bands. The former interpretation seemed to be more in keeping with the earliest observations at Edinburgh and Harvard College. But there are two regions on the plates, which cannot be accounted for on the supposition of a strong continuous spectrum. These are the region near Hβ on the violet side, and the region between Hδ and Hϵ : these are much too weak, when compared with the strongest parts between Hβ and Hγ, to be considered continuations of the same spectrum. The later photographs of March 22, 25, and 28 seemed to decide the question in favour of the bright blue bands by their greater prominence on a weaker continuous spectrum.

2. *The bright hydrogen lines* are probably the broadest radiation lines yet observed in stellar spectroscopy. In the following table their widths on the negatives are given in millimetres, with a column of means reduced to spectral widths in wave-length micromillimetres :—

Table I.

Widths of Hydrogen Bright Lines.

	On March 3 mm.	16 mm.	27 mm.	April 4 mm.	16 mm.	Mean mm.	$\mu\mu$
Hβ	0·44	0·34	0·35	0·33	0·29	0·35	3·5
Hγ	·68	·63	·56	·48	·53	·58	3·5
Hδ	·78	·79	·59	·64	·53	·67	3·4
Hϵ	·83	·81	·72	·59	·68	·73	3·2
Hζ	·96	·89	·72	·72		·82	3·3
Hη	·78	·77	·60			·72	2·7

These figures show an apparent gradual shrinkage of the lines. But it may be doubted whether this is a real contraction or only the result of decreasing intensity. The widths on March 3 and 16 are exaggerated by over-exposure of the hydrogen spectrum ; and those of March 27 and April 4 may be broadened in the same way by a rate of trail slower than was intended for the diminished magnitude of the star. On the other hand, the trail was too quick on April 16, through an accidental omission to adjust the clock rate ; but the definition

is very perfect on this plate, and the broad lines are sharply margined on both sides, so that there was no hesitation in setting the micrometer line upon them. It is not impossible that these are the real measures stripped of all photographic encroachment and marginal indefinition.

Changes in the structure of the lines are apparent on the plates. Some of these are of undoubted radiation origin, and others may be only photographic freaks. In the following details doubtful appearances will be omitted, or noted as such.

On February 28 Hβ and Hζ are very clearly crossed by central absorptions. The same reversal is just seen in Hδ, doubtfully in Hγ, but not at all in Hϵ or Hη.

On March 3 the same reversal is seen in Hβ only, and it appears broader on the plate at 12 hours than on the earlier plate at 8 hours.

On March 12 there is a notable change : the reversal in Hβ has gone, and in its place there is a line of *greater* intensity, accompanied by two others, one near each margin of the broad line. The same triple structure appears also in Hγ and Hδ, but not in the other lines. Hϵ is composed of two equal parts of unequal strength sharply distinct, with the stronger half on the red side.

On March 16 the triple structure is much weaker, and the double-banded appearance of Hϵ is changed to a maximum strength nearer to the red side, shading off both ways ; and all the other lines, excepting Hβ, show this distribution of density.

On March 20 the triple intensity is still seen in Hγ, and the double-banded appearance of Hϵ is restored.

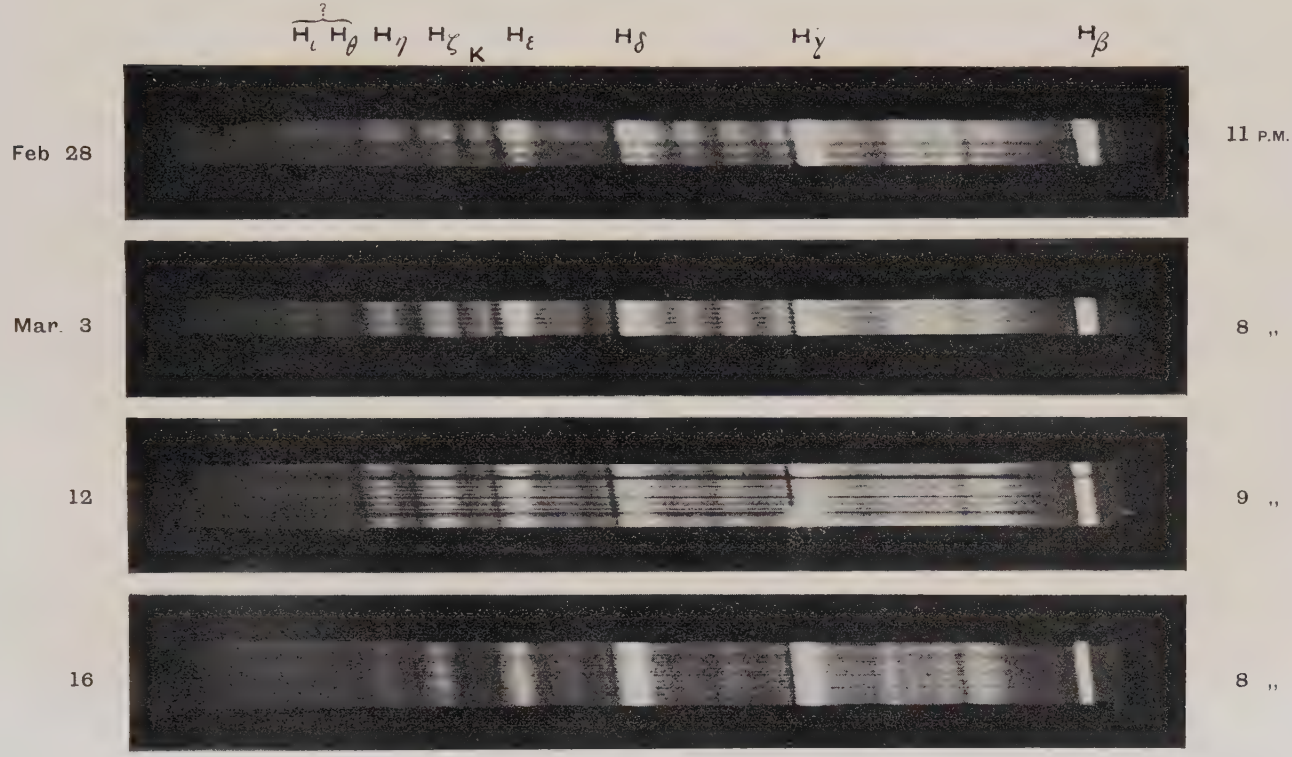
On March 21 all the markings are gone and the greatest strength remains on the red sides of the centres, excepting Hβ, which is of uniform intensity from side to side.

On March 22, 25, and 28 Hζ is left out of consideration as belonging to a new spectrum to be discussed in paragraph 7. On these dates the general red-side-greater strength appears only in Hγ.

On March 27 the central reversal has reappeared in all the lines except Hη, which is, perhaps, too weak to show the contrast. It is not sharp in any of the lines, and admits of the negative interpretation of less radiation, as opposed to the positive action of a reversing absorption. The general greater intensity of the red sides of the lines is restored to Hδ, Hϵ, and Hζ ; and Hβ retains its uniform appearance.

On April 4 all the lines, including Hβ, are stronger on their red sides, except Hζ, which has a very marked maximum on the more refracted side of its centre.

On April 9 Hγ alone retains a red side excess of strength, the other lines being nearly uniform, with fairly sharp edges. And this remains the general character of the hydrogen spectrum to the end of the month, excepting only those changes which belong to paragraph 7.



SPECTRUM OF NOVA PERSEI, 1901

3. *The calcium line* K was bright and broad like the hydrogen bright lines on February 28 and March 3, and since then it has slowly faded away. It was marked with a central reversal, and the more refracted half was much the weaker. This was the first to disappear; it was weaker on March 7 and 8; and on March 12 it was extinct; but the reversal remained as a companion to the stronger component. On this date the reversal was a strong, sharp, and thin line on the more refracted side of its bright companion, resembling the dark companions of the hydrogen bright lines, but retaining its position of the K wave-length relatively to the bright hydrogen series. It is again apparently marked on the plate of March 16, but only about half across the plate, viz. during the first part of the trail; and so, if real, it was extinct at 8.30 P.M., the trail having started at 8^h and ended at 9.15. Its position is exact; and it is very nearly, if not perfectly, parallel to Hϵ. It divides nearly centrally a feebly bright space, which may be calcium radiation nearly extinct; and this trace of calcium light is seen again, and for the last time, on a plate of the 21st without the reversal.

4. *The dark hydrogen lines* do not appear to have been, at any time, very broad; not much broader than those of α *Geminorum*.

In the first photographs of February 28 and March 3 there is nothing against the possibility of a much greater width masked by the overlapping broad bright lines. But on the later photographs they stand apart from the bright lines, with perfectly sharp edges, and the broad bright lines fade away towards them in the same manner as they fall off on the red sides. This is very clearly seen in Hδ, Hϵ, and Hζ in the enlarged spectrographs of March 12, 16, and 21.

At the beginning these dark lines appeared to grow in strength, between February 28 and March 8; but the evidence for this is not conclusive: the apparent increase of intensity may be a photographic effect due to difference of exposure. But after March 8 their decline was regular and uninterrupted; they slowly disappeared, together with the bright calcium line K. On March 12 they had lost their centres, and appeared as well-defined double lines separated by a thin clear reversal. The more refracted components were much the weaker and were the first to disappear. They had lost much on the 16th and were quite extinct on the 20th, when the red side components formed the series of sharp thin lines, which were seen for the last time on the 21st.

5. *The separation of the bright and dark hydrogen lines* is still the most important feature of a *Nova's* spectrum. The separation in this spectrum is so great that it is not necessary to wait for direct determinations of displacement with reference to terrestrial hydrogen light in order to arrive at sufficiently approximate conclusions, on Doppler's principle, regarding the line of sight velocities. The measured length of the hydrogen

spectrum compared with that of a reference star, on the method described by Orbinsky,* may be considered enough for the investigation of velocity by small dispersion, when an error of 50 miles is of no great consequence.

For this investigation the reference star selected was *α Cygni*, on account of its sharply defined hydrogen lines. Four exposures have been made with the correct *setting*, described in the introduction, and three with a faulty setting, more at fault than could occur accidentally. All these have been carefully tested on the micrometer stage; and the agreement of the measured lengths from Hβ to the several hydrogen lines up to Hμ is expressed by the greatest difference between the same measures on any two of the plates being ·02 mm. Repeated measures of the same intervals on the photographic plates of the *Nova* have been made, and the results are summarised in the following table; in which the figures of column j are the measured lengths from Hβ to the successive hydrogen lines in the spectrum of *α Cygni*, and those of column ij are the corresponding lengths in the dark-line series of *Nova Persei*. In column iij the differences are entered, and in column iv the deduced velocity. In columns v, vj, vij, viij the bright lines are treated in the same way as the dark lines in j, ij, iij, and iv :—

Table II.

Radial Velocity.

Hydrogen.	Dark line spectrum.				Bright line spectrum.			
from Hβ to	Length α Cygni. j. mm.	Length Nova. ij. mm.	Diff. iij. mm.	Deduced velocity miles per sec. iv. —	Length α Cygni. v. mm.	Length Nova. vj. mm.	Diff. vij. mm.	Velocity Miles viij. +
Hγ	6·990	7·081	·091	720	6·99	6·95	·04	320
Hδ	11·376	11·509	·133	740	11·38	11·33	·05	280
Hε	14·268	14·426	·158	700	14·27	14·23	·04	†180
Hζ	16·226	16·428	·202	770	16·23	16·15	·08	300
Hη	17·625	17·835	·210	710	17·62	17·54	·08	270
Hθ	18·654	18·878	·224	720				
Hι	19·433	19·660	·227	690				
Hκ	20·032	20·263	·231	700				
Hλ	20·505	20·745	·240	710				
Hμ	20·882	21·120	·238	680				
		Mean		— 714.		Mean		+ 270 .

No great accuracy is to be expected in the resulting velocities. But the figures afford an independent demonstration of

* Observatory, 1895, 303.

† There is some reason for mistrusting the apparent centre of this line on account of the presence of other lines, as may be gathered from the remarks upon the line 396·9 in the Appendix.

high velocities in opposite directions, together with an approximate measure of their magnitudes. Those from the dark-line spectrum rest on the measures of a single plate for the greater intervals at $H\iota$, $H\kappa$, $H\lambda$, $H\mu$, and on three plates for the shorter lengths.

There was little difficulty in setting the micrometer wire on the absorption lines, which are sharp and well defined. It was different with the broad bright lines, but for these many plates were available; and the mean intervals obtained from them should give a fairly reliable resulting velocity, seeing that the individual measures are not very erratic. The following table contains an abridged analysis of these measurements, designed to show the relation between the *means* and the separate measurements :—

TABLE III.

Analysis of the Measurements for the Bright-line Velocity.

Relation between the *means* and *separate measures.*

From Hβ to		Hγ	Hδ	Hε	Hζ	Hη
Mean length	mm.	6·95	11·33	14·23	16·15	17·54
Number of plates affording a measure		26	22	23	14	12
Range, or difference between extreme measures	mm.	·07	·09	·13	·21	·33
Number of measures giving the opposite sign		1	1	3	0	1

The resulting velocities were in both cases unexpected, as may be seen by a reference to the writer's earlier notes on the spectrum of *Nova Persei* in the *Monthly Notices*,* in which it was stated that the whole of the relative velocity would probably have to be attributed to the dark-line source; the measured lengths from Hβ to the successive bright lines being the *same* in the spectrographs of the *Nova* and of the comparison stars. The *differences* have been found by comparisons with the thinner and more sharply defined hydrogen lines in the spectrographs of *α Cygni*, obtained at the end of May and beginning of June.

There is no evidence from this investigation of any change of the velocity of the bright-line source between March 3 and April 26; but, so far as the measures can be trusted, the evidence is for a constant velocity. Of the total number of plates measured, eighteen belong to March and eight to April; and the mean lengths are compared in the following table :—

TABLE IV.

From Hβ to	Hγ	Hδ	Hε	Hζ.
Number of plates in March ...	18	17	17	12
„ „ April ...	8	5	6	2
Mean length in March ...	6·95	11·33	14·23	16·15
„ „ April ...	6·95	11·33	14·22	16·17

* April 1901, Note 2.

6. *The general spectrum of the star* is treated as two distinct spectra, called for convenience the *approaching* spectrum and the *receding* spectrum. The receding spectrum is taken to consist exclusively of bright lines. These are, with few exceptions, like the hydrogen lines, broad and somewhat diffuse ; and they are supposed to be under the same physical conditions which affect the position and breadth of the hydrogen lines.

The wave-lengths are quoted for the centres of the broad lines ; the centre of bright Hβ has been employed for the fiducial point in the receding spectrum, and the wave-lengths have been corrected for velocity-displacement.

Similarly, in the approaching spectrum the centre of dark Hβ, or of dark Hγ, according to the circumstances of the plate, has been used for the fiducial point, and the displacement correction applied accordingly.

In both spectra, therefore, the tabulated wave-lengths are, as nearly as can be obtained from the spectrograms, the undisturbed wave-lengths of the origins, or as they would be found from a stationary source. A test line for the corrections of the receding spectrum is the reversed K, which is a thin sharp line on the plates of March 3, 12, and 16, and owing to the applied correction appears in the table with its undisturbed wave-length.

The tables are to be found at the end of the paper ; and the lettering of the columns and explanations are given in the notes at the end of the tables.* In the first column of the bright-line table some possible origins are noted, which are collected together in the following list. The wave-lengths are taken from Watts' Index, excepting those of helium, which are the strongest lines in Runge and Paschen's list : †—

TABLE V.

Possible Origins of Bright Lines.

Nova. λ	Width. μμ	Helium. Max. I. 10.	Oxygen. Max. I. 10.	Magnesium. Max. I. 10.	Vanadium. Max. I. 10.
403·3	1·7	402·6 5			
407·0	2·1		406·9 6 407·1 6 407·5 6		
438·3	Thin	438·8 3			437·9 10 438·4 1 439·5 6
447·1	Thin	447·2 6			

* It was originally intended to give the tabulations separately for the dates at the heads of the columns of spectrum I. and spectrum II., which are respectively the *old* and the *new* spectrum of the text. But when it was found that another new spectrum was presented in August, it was decided to put the three spectra together side by side, and to simplify the tabulations of all.

† *Harvard Coll. Ann.* xxiii. pt. i. p. 123.

Nova. λ	Width. μμ	Helium. Max. I. 10.	Oxygen. Max. I. 10.	Magnesium. Max. I. 10.	Vanadium. Max. I. 10.
447·9	0·7			448·1	
457·2	1·7			457·1 10	
458·6	Thin				458·5 6
464·0	3·0		463·7 6 464·1 7 464·8 9		
471·7	Thin	471·3 3			
491·9	3·4	492·2 4			
501·5	3·2	501·6 6			
				517·9 9	
516·7	3·9			518·3 10	

Also on March 28	385·7	*Cyanogen*	385·7	7
	386·1	,,	386·2	8
	388·2	,,	388·3	10

An interesting result appears by collating the two tabulated spectra : viz. that the broad bright line near Hδ and the broad absorption on its more refractive side, which are well seen in the enlarged photograph of March 3, &c., are complements, having, practically, the same wave-length, 407·0 and 406·9, in their respective spectra. The line has a strong claim to represent the oxygen triplet, as noted in the table above ; and therefore oxygen appears to share the physical conditions of hydrogen in the *Nova*.

Other complementary lines, indicated in the same manner, are the fine lines

461·5	459·6	438·6 bright	on March 17.
461·4	459·3	438·5 dark	

7. *The alternating spectrum* of the *Nova* was first observed as such on March 28, when the photograph of the preceding day showed that the remarkable change seen in those of the 22nd and 25th was not a permanency. The changed spectrum is to be found on Plate 2 of enlarged photographs, on the dates March 25 and 28, which are in all details the same as the photograph of the 22nd. Its leading features are the broad blue lines or bands in conspicuous contrast on a much enfeebled continuous spectrum, and an apparent great extension of the bright hydrogen line Hζ. On the same plate is shown the return to the older spectrum on the 27th ; and the two similar spectra of the 21st and 27th show that the change from the old to the new spectrum on the 22nd and 28th was very rapid.

The three dates, March 22, 25, and 28, on which the new spectrum was first seen, corresponded closely with the observed

minima in the star's light curve ; and the star was supposed to be a variable with a corresponding variable spectrum. But the three-day period failed at the end of the first week of April, the alternations of light intensity became irregular, and the spectrum followed the irregularities of the light. In the following table the dates of the two forms of the spectrum are given from March 21 to April 26 ; opposite each date the magnitude of the star is quoted from the measures made at the Radcliffe Observatory, Oxford,* and the items are written in the order of

TABLE VI.

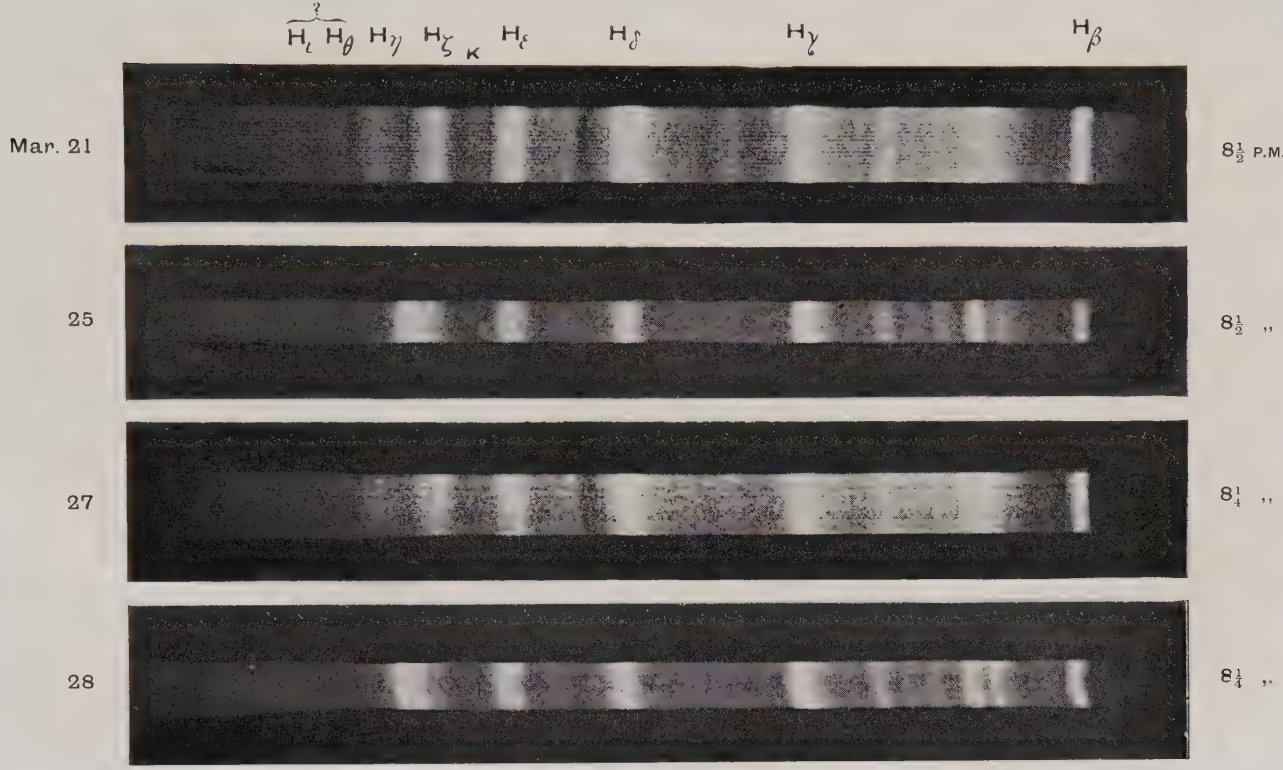
The Alternating Spectrum.

Star's Magnitude.	On Date	
3·91	March 21	
3·98	,, 27	Old type.
4·08	April 4	
4·19	,, 1	
4·28	,, 5	
4·36	,, 23	
4·49	,, 13	
4·57	,, 9	Both types partly.
4·61	March 28	New type.
4·67	April 12	
5·15	March 25	
5·20	,, 22	
5·32	April 16	
5·55	,, 26	
5·83	,, 20	
5·86	,, 25	
6·00	,, 21	

decreasing magnitudes. These figures show that the *new* spectrum is not connected with any phase of the light curve, but follows the absolute light intensity. All the *new* spectra have appeared when the star was less than 4·57 mag., and the *old* spectra only when the star was brighter ; and this magnitude seems to indicate the temperature at which the change takes place : for the spectrum on this date, April 9, belongs partly to both types, the *old* and the *new*, as may be seen by a reference to the writer's note 4 in the May number of *Monthly Notices*, p. 463.

Of the blue bands in the new spectrum, the first (counting from Hβ) is a new radiation, λ 468·7 and the stronger one near it, λ 464·1, is also new if compared with the spectrum of

* *Monthly Notices*, 1901 April and May.



SPECTRUM OF NOVA PERSEI, 1901

Stonyhurst College Observatory

March 21 ; but it is within the very wide band at λ 465 $\mu\mu$ of March 3 and February 28. The fifth band (third in the order of brightness) is the helium line 4472, and is probably new ; but it is broad enough to contain the magnesium line 448, which was the centre of the band on and before March 21. The less refrangible helium line at 471·8 is only just discernible in the negative of March 28, not seen so well as on March 16 and preceding dates.

The apparent extension of Hζ is also a new radiation, probably the cyanogen band between λ 388 $\mu\mu$ and 386. It is crossed by three distinct brighter lines, 388·3, 386·1, and 385·7, agreeing closely with the strong CN lines of intensities 10, 8, 7 in Watts' Index of spectra ; but there is no trace of the line 387·1 of intensity 9. The band is brighter than Hε and nearly equal to Hδ in intensity.

Hε itself is too strong both with reference to Hδ and to the part of Hζ which is not overlapped by the CN band ; and this disproportion in the gradations of intensity becomes a marked characteristic of the new spectrum on April 16, 20, 25, and 26, when Hε appears on the plates with double the strength of Hδ, although at the low altitude of the star on these dates the line should have been obliterated by atmospheric absorption. It is therefore probable that this is another new line.

Review.

At the end of a rather long study of the photographic plates of the *Nova's* spectrum, two questions appear to stand over, about which some expression of opinion may be expected. The first of these regards the high velocities : is Doppler's principle of motion in the line of sight to be accepted or rejected for the true cause of the great displacements of the hydrogen lines ? And the second is about the new type spectrum first photographed on March 22 : what is its teaching ?

In an article "The New Star of the New Century" in the May number of *The Observatory*, the writer acknowledged his own dissatisfaction with the Doppler explanation of the velocities, mainly on account of the want of a general law, according to which the high velocity of the dark-line source in all new stars should be towards our Earth. This want was supplied by Lord Kelvin in a conversation at the Royal Society Soirée in May, and with his permission was explained verbally at the following meeting of the Royal Astronomical Society. The explanation subsequently appeared in the June number of *The Observatory*, and is reprinted here with the kind permission of the editors :—

"Granted a collision between two stars, the immediate result would be scattering of matter in all directions, with greatest velocities in directions nearly perpendicular to the line of relative motion of the two impinging bodies. These velocities of fragments may largely exceed that of the relative motion of the

two bodies before impact. The matter thus scattered would consist not only of the broken bits but also of their decomposed constituents. Ubiquitous hydrogen would be there to begin with, and much also would be liberated. A part of this gaseous mass would be raised to high temperature, with little associated kinetic energy; and a part would be urged outwards at high velocity, with little rise of temperature; and this, the cooler gas, would be the absorbing material. The absorber therefore would always be in motion towards us, and the radiant matter would remain at comparative rest. The application of Doppler's principle then becomes simple. The mass of hydrogen moving away from the white-hot centre would absorb shorter wave-lengths of the white radiation, and would *not* absorb the radiation of glowing hydrogen. The bright lines would therefore be little or nothing displaced on the continuous spectrum, and the dark lines would always be shifted to the side of greater refraction."

The explanation requires the actual collision of two solid stars to account for the enormous velocities needed for the Doppler explanation: no multitude of smaller masses in collision could produce the same effect; and no intrusion of a big solid mass into an ocean of nebulous matter would be more successful. In these hypotheses the fatal assumption has to be made of antecedent high velocity in a given direction. On the other hand, actual collision seems not only possible, but almost a certain occurrence from time to time in the vast and crowded region of the Milky Way; and no imagination can picture the results of the shock of two worlds meeting.

The second question regarding the alternating spectrum is more perplexing. The first change was great and sudden, resembling the quick transition from the white star spectrum to that of gaseous radiation in the earliest days of the star's appearance. But the change was not permanent; the old spectrum returned, and the two types of spectrum alternated quickly, at first periodically, and then at more or less irregular intervals. The quick transitions would be in keeping with some form of eclipsing revolution, but eclipses could not account for the development of entirely new radiations.

A suggestion was made by Sir William Huggins, as far back as 1866, in connection with the new star of that year in *Cygnus*, that the outburst of heat and light might be attributed to "a chemical action of some of the escaping highly heated gases from within, when cooled by the sudden expansion, which might give rise to an outburst of flame at once very brilliant and of short duration."* This hypothesis offers a much-wanted explanation of the oscillating spectrum of the *Nova* in the last days of March. The sudden expansion of a vast mass of mixed gases would naturally become oscillatory for a length of time, the temperature oscillating with it; and when the mean temperature of the oscilla-

* *Atlas of Representative Stellar Spectra*, p. 15.

tions was near the combining temperature of some of the mixed gases, the spectrum would also oscillate with the temperature.

This hypothesis has apparently been revived more recently * in a modified form, which does not appear to suit so well the requirements of oscillation. The difficulty comes in when, for the sudden expansion, radiation is substituted for the cooling agent. This is necessarily a slow process, and something is wanted to keep back the chemical action until the mass of elements ready for combination is great enough for the enormous evolution of heat required. Without this the result is only a retardation of the rate of cooling, as crystallisation arrests the fall of temperature of a cooling liquid. It is true that water may be cooled down several degrees below its freezing temperature, and when the ice forms the temperature rises; and we have, on a small scale, in the opposite process of heating water, an irregularly oscillating temperature about the boiling-point, when the generation of steam becomes rapid. The reach from these small operations to those that would be required for an oscillating stellar temperature is very great; but every supposition made implies some forbidding magnitude, and here the greatness is not greater than the step from the laboratory to the stellar experiment.

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Appendix.

On August 24 and 27, September 5 and 11, and October 4 and 6, good photographs of the *Nova's* spectrum were again obtained, and these show further changes which may be found to be connected with the fall of temperature during the interval.

The photograph on August 24 shows all the broad lines distinctly, but not the finer details: the rate of trail was too slow, and the stronger bands were over-exposed. The plate of September 11 shows, on the contrary, the details of the stronger bands distinctly, but the trail was too quick for the weaker bands.

The reproductions on Plate 3 are from the photographs of August 27 and September 5. The first of these is by the Hilger compound prism (marked H in the tabulations) on the large equatorial; and the second is by the Thorp 4-inch objective prism, T. The first shows the lines better in the blue and green, but loses the violet and ultra-violet by the great absorption of its dense flint glass. The second supplies the violet end of the spectrum. But all the bands can be seen in both.

Other photographs on September 14, 15, 21, and 24, in less favourable atmospheric conditions, serve to show that the spectrum has remained constant in September. It still retains

* Lohse, cited by Vogel, *A.N.*, 3701, and *Edinburgh Review*, 1901 July, p. 89.

its general character of broad bright lines on a distinct continuous spectrum, which perhaps cannot be called weak considering the small magnitude of the star. The principal changes are contained in the following notes :—

1. The hydrogen lines are no longer the prominent features. They are weak uniform bands, and are apparently dying out without losing anything of their width.

2. The two significant lines 500·7 and 495·8 have come into prominence, in place of the two helium lines 501·7 and 491·9, which have disappeared.

3. The blue helium line 447·2 has died out, and another, a weaker line in the laboratory, 471·3, has grown from a feeble intensity to be one of the strong lines of the spectrum : it is the strongest on the isochromatic plate by the prism H.

4. The strong broad blue band 468·7 of the new spectrum in March and April has contracted to a narrower and weaker band, at 467·9.

5. The hydrogen line Hγ and its companion band at λ 436·4 have exchanged conditions of relative intensity, the latter now being much the stronger. These two broad lines have been close companions from March 21. They overlap one another, and the overlapping edges can be seen in the photographs of March 21 and subsequent dates. They are very clear in the photographs of August, September, and October, and in these the overlapping strip is much stronger than the united intensities ; it has been interpreted as a bright line in the structure of the band 436·4, and is proved to be so by a photograph on September 15, in which it appears as a strong line on this band when Hγ and the other hydrogen lines have failed to mark the plate.

6. The three bands, 386·9, 396·9, and 436·4, are marked symmetrically, each with four brighter lines, and the brightest near the more refracted edge.

7. The strongest lines by prism T are 386·9, 396·9, 436·4, and 471·3, in order of decreasing intensities ; and of these the three first are apparently at the same intensities as in March and April. On March 25 the altitude of the star and the circumstances of the plate (exposure and development) were the same as on September 5, and the intensities of the bands are practically the same on both dates. But in March the bands had nebulous edges, and in September they are compact bands with well-defined edges, as on April 16.

8. The most energetic radiations of the star, allowing for appearances depending upon instrumental defects, are λ 386·9 and 500·7. It is not clear which of these is the stronger. The former is the strongest by prism T, and appears as a distinct though feeble band on the photograph by prism H, notwithstanding the prism's great absorption of this light ; while the latter is a strong line by prism H, although its position on the sensibility curve of the isochromatic plate is rather low down in the hollow between the blue and yellow maxima, and the line is

distinctly marked on an ordinary quick plate employed with the prismatic camera, although the sensibility of the plate to this radiation is very small. But this plate affords a direct comparison between the intensities of the *Nova* and the corresponding places in the continuous spectrum of *α Cygni*. The two spectra are not on the same plate, but both plates are Mawson's quickest, and the exposures and developments were practically the same, the exposure on *α Cygni* having been made with the object of bringing out every possible detail at the two extremities of the spectrum. In this comparison the line 386·9 of the *Nova* is decidedly stronger, and the line 500·7 a little stronger than the corresponding parts of the spectrum of *α Cygni*. The preference therefore is given to the ultra-violet line, and the probable order of real intensities in the *Nova*, beginning with the strongest, is 386·9, 500·7, 495·8, 472·0, and 436·4.

These and the weaker lines are entered in Table VII. under the name of spectrum III. ; and the line-details of broad bands are given separately. These wave-lengths are not corrected for any velocity displacement, no indication of displacement having been found. On the photographs of August 27 and September 5, Hβ and Hδ appeared with well-defined edges admitting of accurate settings of the micrometer line, and no relative displacement was found.

We have, at Stonyhurst, no photographs of the spectrum between April 26 and August 24 ; and, unfortunately, no orthochromatic plate was employed in March or April : so that our series of photographs leaves it uncertain whether the new lines 495·8 and 500·7 on August 27 belong to the second spectrum, or to a further decrease of stellar temperature. The change at the position of Hϵ, where the band 396·9 is so much stronger than the other hydrogen lines, appears to be connected with the star's magnitude 5·32 on April 16, when Hϵ was stronger than Hδ ; it was not so on a later date (April 23), when the star was much brighter, and it was not so on an earlier date (March 22), when the star was a little brighter—·12 mag.—and it was always so later, when the star was less bright than 5·32 mag. But the structure of this band, and the similar structure of the bands 386·9 and 436·4, belong probably to a later stage of the star's decline.

Of the changes, therefore, enumerated, perhaps only the following are to be associated with the lower temperature of the later spectrum : 1, the development of the band 472, which was weak and hazy in the second spectrum, into a strong band containing a stronger line at 471·3 ; 2, the shrinking of the strong band 468·7 of the second spectrum to a weaker and thinner band at λ 467·9 ; and 3, the quadruple structure of the three bands 386·9, 396·9, and 436·4.

The other changes may have taken place at higher temperatures. Thus the compact form of the bands is apparently a marked feature of the later spectrum—a change from diffusive

edges to sharp margins ; but from the photograph on April 16 this form appears to have been assumed at a higher temperature, when the star's magnitude was 5·32. Similarly, the predominating intensities of the lines 386·9 and 396·9 appear to indicate a comparatively permanent state of radiation, dating from the beginning of the second spectrum, and brought into relief by the failing of other lines, rather than by any growth of their own intensities.*

Conclusion.

It must be admitted that the latest spectrum of *Nova Persei* has not contributed to a better understanding of its earlier forms ; and has raised new questions, or possibly only emphasised old ones, which need solutions before we can read with certainty the messages from temporary stars. The great width of the lines was the leading difficulty at the beginning, but it was not insurmountable. Enormous velocity, or enormous pressure, could not be considered improbable physical facts, associated with the certainly enormous evolution of heat implied by the rapid rise of the star from nothing to the brightest in the sky. But the undiminished width of the lines during the last five months has strengthened the besetting difficulties : high velocity and great pressure present less difficulty when lasting for a short time ; but the hydrogen lines are as broad to-day as they were in the middle of April, and show no signs of losing width : they are apparently dying out uniformly, without thinning at the edges ; and the edges are now too firm and too sharp to give the impression of widening by velocity or by pressure.

The questions raised by the present form of the spectrum are not altogether new, but they are more pointed now that they are presented by a purely bright-line spectrum, without the crowded absorptions which might anywhere obliterate a bright line or reduce its intensity to an apparent abnormal relation to others of the same origin. The broad strong line 396·9 might belong to hydrogen, to helium, or to calcium ; but whichever be supposed, the question comes : Why are the usually stronger lines suppressed ? The calcium spectrum has been studied by Sir William and Lady Huggins, in relation to the density of the vapour giving the spectrum.† And they have found that in an extremely rarefied state of the luminous vapour there remain only the two strongest of its lines, known as H and K of the solar spectrum. But at every stage of the experiments the line K was the stronger, and both had become thin lines, losing their broad wings with diminishing density.

As a calcium line, therefore, in the *Nova*, it would be too strong and too broad, and without its inseparable stronger companion at K. As a hydrogen line it would be a case of the

* Cf. Notes, 7, p. 49.

† Huggins, *Atlas of Stellar Spectra*, p. 101.

weakest of four becoming stronger than the united intensities of the rest. And as a helium line, it would be a naturally weaker line in full strength while the strongest are wanting. But of these as possible origins helium, perhaps, is the more probable. Taken for the helium line 396·5, there would be, in all, three helium lines in the spectrum, 386·8, 396·5, and 471·3; all composite lines, but not all symmetrically marked, and not symmetrically widened, the centres of the three bands in the *Nova* being to the red sides of the helium lines at 0·1, 0·4, and 0·6 $\mu\mu$ respectively.

It may be in the future of spectroscopic work to discover the physical conditions of radiant matter when giving these anomalous spectra; but the simpler supposition of an unknown common origin of the three bands 386·9, 396·9, and 436·4, suggested by their perfect similarity in form and structure, may be true, and is perhaps more in keeping with our imperfect knowledge of the luminous spectrum.

But what is the origin? Should it be called Nebulum? Professor Pickering, writing at the end of June, points out the likeness, with some exceptions, between the spectrum of the *Nova* and that of the nebula N.G.C. 3918.* The likeness has improved since then in some respects, for the relative strength of the line 500·7 is better, and the line 436·4 is clearer: the former is now considerably stronger than Hβ, and the latter much stronger than Hγ. And there is no mention of the line 464·0, which was the strongest of the blue bands in the second spectrum, and is still equal to Hγ; while the other strong line 468·7 has either completely fallen out, or is masked by two side lines, a weaker one at λ 467·9, and the practically new line 472·0, which is now the strongest of the blue bands. But is not the likeness spoiled by the great width of the *Nova's* lines, and by the composite structure of four of the strongest bands?

Table VII.

Bright-line Spectrum of Nova Persei, 1901.

Spectrum	I.			II.			III.								
Prism	T.			T.			T.			H.			T. and H.		
Date	Feb. 28, Mar. 3, 12, 16, 21, 27.			Mar. 22, 25, 28.			Aug. 24, Sept. 5.			Aug. 27.			Oct. 4, 6.		
Nova Magnitude	Mag. >4·57.			Mag. <4·57.			6·21.		6·42.	6·48.			6·86.		
Possible Origins.	λ $\mu\mu$	W $\mu\mu$	i 10/1	λ	W	i	λ	W	i				λ	W	i
	376·4	1·7	2												
Hθ	379·8	2·6	8												
Hη	383·5	2·9	5												
Hζ	388·9	3·3	6	386·9 388·9	6·0	8	387·0	2·9	10	387	2·3		386·8	T.	2·5

* *A.N.*, 3735, p. 234.

Spectrum	I.			II.						III.					
Prism	T.			T.			T.			H.			T. and H.		
Date	Feb. 28, Mar. 3, 12, 16, 21, 27.			Mar. 22, 25, 28.			Aug. 24, Sept. 5.			Aug. 27.			Oct. 4, 6.		
Nova Magnitude	Mag. > 4·57.			Mag. < 4·57.			6·21.	6·42.		6·48.			6·86.		
Possible Origins.	λ μμ	W μμ	i 10/1	λ	W	i	λ	W	i				λ	W	i
K	393·3	1·9	5												
Hε	397·0	3·2	7	397·1	3·4	8	396·8	3·2	8	396·8	2·5		396·8	T.	2 3
He 402·6	403·2	3·2	3	403·1	2·2										
O triplet	407·0	2·1	4	407·0											
Hδ	410·2	3·4	8	410·2	3·0	9	410·2	3·0	2	410·1	2·3				
	413·0	2·2	6	414	3	1									
	417·4	2·9	6	419	3	1									
	423·4	2·3	6	423·5	3	1									
	430·3	2·5	6	428	3	1									
Hγ	434·1	3·5	10	434·1	3·1	10	434·1	2·6	2	434·0	2·5		434·1	H.	2·3
O 436·4*				436·4	3·0	3	436·4	3·0	7	436·3	2 8		436·3	H.	3·0
	438·4	4·5	7	438·4	2·5	2									
He 447·2				447·1	3·2	4				447·1	2·7†		447·1		2·7†
Mg 448·1	447·9	0·7	7												
	452 0	1·5	7	452·3	3·3	1									
Mg 457·1	457·2	1·7	7	457·1	3·3	2									
O triplet				464·1	3·3	9	464·0	3·2	2	463·9	3·0		463·9	H.	2·5
	465·0	6·3	7												
							467·9	1·1	2	467·9	1·3		468·0	H.	2·1
	468·7	2·5	5										470·0	H.	thin
He 471·3	471·7	thin	1	471·8	3·0	1	471·8	4·0	6	472·0	4·2		472·1	H.	2·0
	482·4	1·2	2												
Hβ	486·1	3·5	10	486·1	3·0	9	486·1	2·7	1	486·1	2·9		486·1	H.	2·7
He 492·2	491·9	3·4		?			?			495·8	2·3		495·8	H.	3·0
He 501·6	501·7	3·2		?			?			500·7	3·0		500·7	H.	3·0
	506·6	thin													
C 516·5	516·7	3·9	Prism H												
	531·0	2·2													
	542·2	3·4													
	547·5	thin													
	553·2	2·9													
	558·1	1·7													

* Huggins. In Watts' Index.
† Very feeble. Other bands can be seen but not measured.

Structure of Bands—Bright Lines.

Band at		386·9.	396·9.		436·3.
On	Mar. 28.	Sept. 5, 11, Oct. 4, 6.	Sept. 5, 11, Oct. 4, 6.	Aug. 27.	Sept. 5.
By prism	T.	T.	T.	H.	T.
C. N. lines.					
		385·6 edge	395·6 edge	434·9 edge	434·9 edge
385·7	385·7 strongest	385·8 strongest	395·8 strongest	435·1 strongest	435·2 strongest
386·2	386·1	386·5	396·5	435·8	435·9
387·1		387·1	397·1	436·5	436·6
		387·8	397·8	437·3	437·4
388·3	388·3	388 2 edge	398·2	437·7 edge	437·8 edge

Band at	438·4.	457·2.	465·0.	467·9.	471·9.	
On	Mar. 3.	Mar. 12, 16.	Mar. 12, 17.	Aug. 27.	Aug. 27.	Sept. 5.
By prism	T.	T.	T.	T.	H.	T.
	436·1	456·1	461·9	467·2	469·8	470·2
	438·6	457·5	463·2	468·1	471·2 strongest	471·3 strongest
	440·4	458·9	464·4		472·4	472·3
	440·6		466·0			
			468·3			

The wave-lengths of spectrum I. and II. are corrected for velocity-displacements. Spectrum III. has given no indication of velocity-displacement.

Prism H is a compound direct prism on the 15-inch O.G. equatorial.

Prism T is a 4-inch objective prism on a 4-inch O.G. finder.

In column W the widths of the lines are given in spectral micro-millimetres.

In column *i* the strongest line on the plate is indicated by the number 10, no allowance being made for the sensibility curve of the photographic plate. The numbers therefore in different columns are not necessarily comparable. The intensities by prism H are not entered, on account of the great absorption effect of the dense flint glass. On this plate the strongest lines are 471·3 and 436·4.

TABLE VIII.

Dark-line Specirum corrected for Velocity-displacement.

λ		On Dates.	
377·1	Hι	Mar. 3, 12.	Also κ, λ, μ, ν on Mar. 12.
379·8	Hθ		All to Mar. 12 inclusive.
381·6		,, 12.	Very clear.
383·6	Hη		All to Mar. 21 inclusive.
386·7		,, 12.	Clear.

λ		On Dates.	
388·9	Hζ		All to Mar. 21 inclusive.
389·5		Mar. 17.	Very clear fine line.
390·7		„ 17.	
391·9		„ 17.	
397·0	Hε		All dates to Mar. 21 inclusive.
399·6		„ 17.	
406·9		„ 12, 17, 20, 27.	Broad.
410·2	Hδ		All dates to Mar. 21 inclusive.
421·6		„ 12.	
434·1	Hγ		All dates to Mar. 21 inclusive.
438·5		„ 17.	Edge of Hγ.
459·3		„ 17.	Very fine, not strong.
461·4		„ 12, 17.	May be only continuous spectrum.
486·1	Hβ		All up to Mar. 21 inclusive.

Stonyhurst College Observatory :
1901 *October* 10.

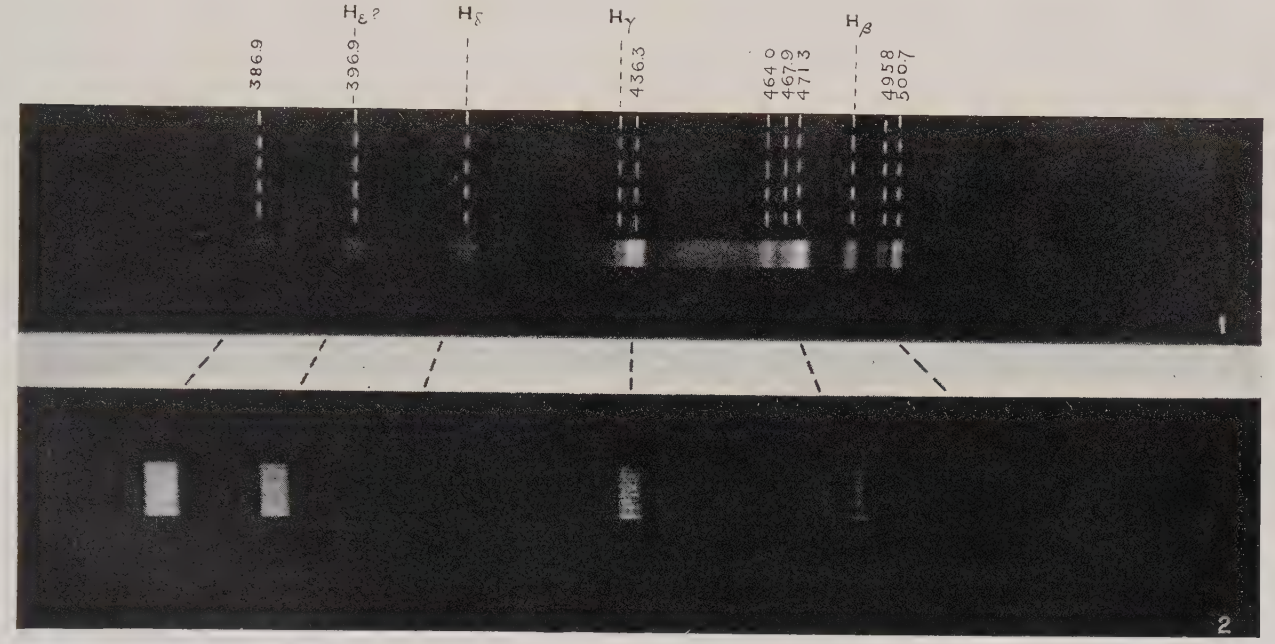
Observations of Nova Persei. By J. E. Gore, M.R.I.A.

I first saw this remarkable object on the evening of 1901 February 22, at 11.40 G.M.T., before I had heard of its discovery elsewhere. It was then much brighter than *α Persei* and seemed to me about equal to *Pollux*, or nearly first magnitude. I have since observed it on every available opportunity, and the following are all my observations to end of 1901 November. The observations were at first made with the naked eye, and afterwards, when the star became fainter, with a binocular.

The following are the comparison stars used in estimating the magnitude of the *Nova*. The magnitudes of the comparison stars are those given in the Revision of the Harvard Photometry. The estimates were made by the method of Argelander :—

Comparison Stars for Nova Persei.

Star.	Mag. Revision of H.P.	Star.	Mag. Revision of H.P.
Capella	0·24	32 (*l*) Persei	5·13
Pollux	1·25	36 Persei	5·27
α Persei	1·85	30 Persei	5·37
β Persei	2·31	(*b*) = D.M. + 44°, 734...	6·50
ε Persei	2 88	(*k*) = D.M. + 44°, 757 }	6·82
δ Persei	3·11	„ 759 }	
ν Persei	3·90	(*f*) = D.M. + 43°, 730...	6·91
κ Persei	4·07		



SPECTRUM OF NOVA PERSEI ON AUG. 27 AND SEPT. 5, 1901

1. BY COMPOUND PRISM ON LARGE EQUATORIAL
2. BY OBJECTIVE PRISM ON 4-INCH FINDER

Stonyhurst College Observatory

Observations of Nova Persei.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Feb. 22	11 40	1·25	A great new star in Perseus between β Persei and δ Persei; preceding, a little north of ν Persei. Much brighter than α Persei and about equal Pollux.
23	11 25	...	Star still very bright but only seen through passing clouds; magnitude uncertain—seems at least first magnitude.
24	10 45	0·24	Nova seen between clouds; seems fully equal to Capella! Very bright; white with tinge of yellow.
26	10 55	1·05	Nova seen through intervals between fleecy clouds; seems much fainter; about one magnitude below Capella and one magnitude above α Persei; strong moonlight.
27	11 45	1·73	Nova about 1 step brighter than α Persei, much fainter than last night; Nova about same colour as Capella, more reddish than α Persei. Nova evidently fading rapidly. About 4 steps brighter than Algol. (N.B.—Algol *not* near a minimum.) Strong moonlight, but stars quite clear and easily observed.
Mar. 1	7 40	2·0	Nova about 1 "step" below α Persei, but not much superior to Algol; clear sky in vicinity of Nova; strong moonlight.
	10 38	2·13	Nova about 2 steps less than α Persei.
2	9 10	...	Nova about same brightness as last night but seen through fleecy clouds; estimate a little uncertain; strong moonlight.
	10 5	2·08	Nova $1\frac{1}{2}$ step below α Persei, and $1\frac{1}{2}$ step above Algol; sky clear round these stars. Nova more yellowish than α Persei. Seemed to twinkle a little more than α Persei.
3	8 30	2·45	Nova $3\frac{1}{2}$ steps less than α Persei, and 1 step less than Algol; very clear sky; strong moonlight. Nova has still an orange tinge.
7	7 5	2·88	Nova about equal to ϵ Persei; but strong twilight, observation a little doubtful, but not very.
	9 38	2·82	Nova = ϵ Persei, and Nova $2\frac{1}{2}$ δ Persei; sky clear in vicinity of Nova; Moon low.
8	11 35	3·11	Nova 2 steps below ϵ Persei and about equal to δ Persei; pretty clear in vicinity; moonlight.
12	10 15	3·31	δ Persei 2 Nova 6 ν; clear sky, no Moon.
13	10 20	...	Nova seems a little fainter than last night, but some clouds about; observation doubtful.
18	11 0	3·90	Nova equal to ν Persei and considerably less than δ Persei; clear sky between passing clouds; no Moon.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Mar. 21	8 55	4·0	Nova about 1 step less than ν Persei, but considerably brighter than 32 (l) Persei with naked eye. Slightly reddish with binocular; might be described as "claret" tint; very clear sky but phosphorescent; no Moon; cold easterly wind.
23	8 15	3·85	Nova 1 step *brighter* than ν Persei and 2 steps brighter than κ Persei with naked eye and binocular; sky clear from clouds, but air very hazy; crescent Moon.
25	12 5	5·22	(32) 2 (Nova) 3 (30 Persei), with binocular; clear sky, but hazy; moonlight. Nova much fainter than ν or κ Persei.
26	8 40	4·05	Nova 1 step less than ν Persei, with naked eye and binocular; much brighter than 32 Persei. 32 rather more than half a magnitude above 30. Clear sky; moonlight.
	10 55	4·18	Nova 2 steps below ν Persei; sky clear in vicinity of Nova.
27	8 55	3·90	Nova *much* brighter than 32 Persei and distinctly brighter than last night; about equal to ν Persei, and (Nova) 1 (κ Persei) with naked eye and binocular; clear sky; strong moonlight.
28	9 5	5·13	Nova = 32 (l) Persei, and (Nova) 3 (36 Persei) with binocular; clear sky; strong moonlight; very cold; Nova much fainter than ν and κ Persei.
29	10 25	4·73	Nova considerably less than ν Persei, but 3 steps brighter than 32 (l) Persei. Seen between passing clouds; strong moonlight.
Apr. 1	9 5	4·35	(ν Persei) 3 (Nova) 5 (32 Persei); clear sky; strong moonlight. Nova visible to naked eye.
6	9 10	5·32	(32 Persei) 4 (Nova) 1 (30 Persei), between clouds; estimate uncertain, but Nova certainly below 32; much fainter than ν and κ Persei.
7	8 40	5·37	Nova equal to 30 Persei and distinctly below 32; very clear sky; no moonlight.
	9 50	5·50	Nova *just* visible to naked eye; 1 step less than 30 Persei; a faint star compared with ν and κ Persei.
8	10 0	4·5 ±	Nova seen in a very hazy sky; seems brighter than last night, but less than ν Persei; about 4·5 mag., but observation uncertain.
	10 25	4·5 ±	Nova again seen; about the same as above.
9	8 50	4·59	(ν Persei) 4 (Nova) 3 (32 Persei), and ν 4 Nova 4 (36 Persei); clear sky; no Moon; Nova visible to naked eye.
	9 45	4·61	ν 4 (Nova) 2 (32 Persei), and ν 4 Nova 5 (36 Persei); very clear sky; Nova very visible to naked eye.
11	11 50	5·37	Nova = 30 Persei, and distinctly below 32; clear sky; no Moon; Nova low down, but observation certain.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Apr. 13	9 15	4·25	ν 2 (Nova) 5 (32 Persei); hazy sky, but observation fairly good; no Moon; Nova visible to naked eye.
14	10 ?	5·44	Nova = 30 Persei, or perhaps 1 step less; *very* clear sky; no Moon.
15	10 15	5·37	Nova = 30 Persei; seen between clouds.
16	9 1	5·50	(30 Persei) 1 (Nova), and Nova considerably less than 32 Persei; clear sky, but hazy and rather bright.
	9 45	5·37	Nova about equal to 30 Persei; very little difference between the two.
18	9 20	4·39	(ν Persei) 4 (Nova) 6 (32 Persei); hazy sky, but observation pretty certain. Nova again increased in brightness; visible to naked eye.
19	8 55	5·33	(32) 5 (Nova) 1 (30 Persei); sky clear, but rather hazy; no Moon; sky rather bright; Nova not visible to naked eye at $9^h\ 30^m$.
20	9 7	5·50	Nova about 1 step below 30 Persei, but sky very hazy, and thin clouds about; observation uncertain.
21	10 2	5·37?	Nova about equal to 30 Persei, but very hazy sky; observation uncertain.
25	9 55	...	Nova scarcely visible through haze, but seems to be faint; $5\frac{1}{2}$ mag. or less.
	10 15	$5\frac{1}{2}$	
27	9 13	4·48	(ν Persei) 4 (Nova) $4\frac{1}{2}$ (32 Persei); pretty clear sky; moonlight.
28	9 45	5·30	Nova faint, about equal to 30 Persei, or 1 step brighter; moonlight and slight haze.
30	9 37	5·37?	Nova faint in the moonlight, and haze and about equal to 30 Persei, but observation uncertain; scarcely visible in binocular.
May 1	9 37	4·5?	Nova barely visible through clouds of smoke, but it seems up again; perhaps 4·5 mag.; less than ν Persei.
	10 20	4·56	Nova brighter than 32, but less than ν Persei; moonlight and haze.
5	1 25	5·50	Nova 1 step below 30 Persei; clear sky; moonlight; star low but fairly well seen; faint, *much* fainter than ν Persei.
6	10 35	5·5?	Some clouds. Nova seems still faint, about $5\frac{1}{2}$ mag., but uncertain.
July 31	12 35	5·87	(30 Persei) 4 (Nova) 5 *b*; clear sky; strong moonlight.
Aug. 6	10 10	5·88	(30 Persei) 5 (Nova) 6 *b*; clear sky; good observation.
8	10 20	5·75	(30) 3 Nova 6 *b*; sky clear but hazy; good observation.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Aug. 10	10 25	6·08	(30) 5 (Nova) 3 *b*; clear sky; no Moon; good observation.
15	10 20	6·12	(30) 6 (Nova) 3 *b*; clear sky; no Moon.
17	10 25	6·05	(30) 6 (Nova) 4 *b*; clear sky; no Moon.
18	10 20	6·12	(30) 6 (Nova) 3 *b*; clear sky; no Moon.
19	10 20	6·12	(30) 6 (Nova) 3 *b*; pretty clear sky, but unsteady air.
20	10 10	6·08	(30) 5 (Nova) 3 *b*; clear sky.
21	10 15	6·21	(30) 6 (Nova) 2 *b*; clear sky; moonlight.
22	10 20	6·25	(30) 7 (Nova) 2 *b*; clear sky but hazy.
24	10 43	6·45	Nova about equal to *b*; hazy sky and moonlight.
25	11 0	6·22	Nova 2 *b*; seen between drifting clouds.
26	12 10	6·22	Nova 2 *b*; clear sky; moonlight.
27	10 40	6·22	Nova 2 *b*; pretty clear; moonlight.
Sept. 4	10 59	6·22	Nova 2 *b*; clear; moonlight.
15	9 25	6·50	Nova = *b*; night hazy; no Moon.
16	9 25	6·22	Nova 2 *b*; pretty clear; no Moon.
	9 58	6·50	Nova = *b*.
17	8 50	6·50	Nova = *b*; clear; no Moon.
20	8 36	6·50	Nova = *b*; clear sky; moonlight.
23	8 40	6·50	Nova = *b*; hazy sky; moonlight.
24	8 49	6·50	Nova = *b*; clear sky; moonlight.
Oct. 2	8 7	6·50	Nova = *b*; clear; no Moon.
4	8 5	6·50	Nova = *b*; clear but hazy.
9	8 45	6·46	Nova 5 *f* and Nova 3 κ; hazy
18	6 55	6·46	Same as last observation.
19	7 25	6·65	Nova 3 *f* and Nova = κ; clear; crescent Moon.
31	7 35	6·80	Nova 2 *f* and κ 1 Nova; clear sky.
	8 0	6·65	Nova 3 *f* and Nova = κ; clear, but a little hazy.
Nov. 14	6 47	6·70	Nova 2 *f*; hazy sky.
16	6 50	6·86	κ 1, Nova 1 *f*; rather hazy.

The Observed Motion and Duration of the Radiant Point of the Perseids. By W. F. Denning.

In recent years a considerable number of observations have been made of the great display of *Perseids* in July and August, and the time seems to have arrived when the results may be usefully summarised. The writer called attention to the motion of the radiant in 1877 August, and reobserved this peculiarity in 1878, 1880, 1885, 1886, 1887, and in several subsequent years. Mr. D. Booth at Leeds obtained some special observations in 1888 and 1891 in examination of this feature, and his figures closely accorded with those previously derived at Bristol (*Observatory*, vol. xi., p. 380).

In tracing the displacement of a radiant it is necessary to keep the observations for each night separate, so that the individual centres for a series of dates may be determined and compared. Before 1893 it appears to have been customary to combine the materials accumulated on several successive or bordering nights, and thus the radiant points, based on such collections, formed diffused positions giving little or no intimation of motion. The necessity of confining the reductions to shorter periods was, however, impressed upon observers, so that in and since the very favourable year 1893 the observations employed in the deduction of the *Perseid* radiant have usually been limited to a single night, and the places determined in this way have proved of much value as evidence in respect of the E.N.E. motion of the shower centre. In the summary which follows I have arranged the radiants observed at Bristol in and since 1874 according to the day of the month on which they were made, and in a separate table have given similar observations by others in and since 1893,* for comparison. It was thought essential to keep the two sets of positions distinct, inasmuch as the Bristol results, if incorporated with the rest, might have unduly influenced the mean values and the deductions based on them. In fact, it seemed safer to arrive at conclusions justified by independent testimony, and to show the degree of mutual corroboration existing between the results derived at Bristol and at other stations. On inspection of the tables this will be seen to be very satisfactory when the nature of the observations is considered. During the last ten years quite a large number of observers have distinguished and followed, as far as conditions permitted, the easterly drift of the radiant, and the rate and direction of the movement have been pretty accurately assigned. As an observational fact this motion cannot be questioned. The writer has long regarded it as one of the most palpable, as well as

* An exception has, however, been made in regard to Mr. Booth's results obtained in 1888 and 1891, as he fixed the place of the radiant from observations on single nights.

one of the most certain, features he has ever noticed in this field of observation. And this trait in the visible character of the *Perseids* is one which appears to be in significant harmony with theory.

Judging from the remarkable increase in meteoric observers in recent years there seems every reason to suppose that the *Perseid* shower (offering as it does a rich display, appearing regularly at the most congenial season of the year) will be more critically studied, and that its radiant point will often be traced as it passes from the southern stars of *Cassiopeia* along the northern borders of *Perseus* into *Camelopardalis*. No doubt this transitory character of the centre is not a feature which is apparent only in the behaviour of the *Perseids*. It is similarly exhibited by the April *Lyrids* and probably by certain other systems, but they are displayed so briefly and often so feebly that it is difficult to glean a sufficient number of well-observed meteors to fix their radiants accurately on nights near the limits of their visibility. On the other hand, a movable radiant is not a common feature, for certain well-defined showers, among which may be instanced the October *Orionids*, show stationary radiants. These peculiarities require further investigation in regard to many of the principal streams. It seems desirable that the *Quadrantids* or *Boötids* of January, the *Lyrids* of April, the *Aquarids* of May and July, the *Orionids* of October, the *Leonids* and *Andromedids* of November, and the *Geminids* of December should all be perseveringly watched in future years with particular regard to their visible durations and to the mobile or fixed radiants which they individually display.

The abbreviations in the list of *Perseid* radiants determined by various observers are :—

E. M. A.	E. M. Antoniadi, Juvisy.
W. E. B.	W. E. Besley, London, S.W.
E. R. B.	E. R. Blakeley, Dewsbury.
D. B.	D. Booth, Leeds.
J. H. B.	J. H. Bridger, Farnborough.
H. C.	H. Corder, Bridgwater.
W. D.	W. Doberck, Hong Kong.
J. A. H.	J. A. Hardcastle, Littlemore, Oxon.
A. S. H.	A. S. Herschel, Slough.
W. H. M. ...	W. H. Milligan, Belfast.
C. D. P.	C. D. Perrine, Lick Observatory.
T. E. R. P. ...	T. E. R. Phillips, Yeovil.
H. J. T.	H. J. Townshend, Leeds.

The observations at Bristol were made at Bishopston, a suburb about two miles north of the central part of the city. During the years from 1869 to 1901 inclusive I observed 8,002 shooting stars on the forty-three nights between July 11 and August 22 inclusive, and these included 2,856 *Perseids*.

With reference to the theoretical conclusions on the displacement of apparent radiant points there is a valuable paper in *Monthly Notices*, vol. lii., pp. 341–54, by the late Joseph Kleiber. Mathematical deductions are here compared with some observational results, and in the case of the *Perseids* they present an excellent accordance. Mr. Kleiber gives the computed place of the radiant on July 8 as 9°+46°, August 8 41°·5+57°·3, August 9 42°·9+57°·6, August 10 44°·2+57°·9, and August 16 54°+59°. Le Verrier first pointed out that theoretically such a displacement must occur, and in 1859 some visible indications of it were recognised by Professor A. C. Twining in America, but the observations were too meagre and inaccurate to prove anything conclusively.

In the lists of radiants I have included those of several very early or late *Perseids* whose real paths were determined from two or more observations, as the places afford a useful corroboration of the radiant positions of the shower at times when it has been but scantily recorded. The real paths and radiants of several hundreds of *Perseids* have been found for dates between August 1 and 14, but it has not been thought desirable to include these, as they were nearly all recorded on August 9, 10, or 11, when the situation of the radiant has been sufficiently well indicated from other observations. The letters "F" and "SS" refer to radiants deduced from duplicate observations of Fireballs and Shooting Stars respectively.

Radiant Points of the Perseids observed by W. F. D.

		α	δ	↙'s
		°	°	
1877–8	July 8–13	11	+48	10
1876–7	July 18	17	+50	4
1900	19	17	+50	SS
1887		19	+51	4
1901	21	23	+52	5
1887	22	25	+52	5
1887	23	25	+52	4
1900		24	+52	SS
1900–1 &c.	24	23	+52	5
1900–1	25	22	+52	5
1878	26	30	+53	5
1887	27	29	+54	5
1883	28	27	+55	10
1887		30	+55	10
1878		32	+53	10
1879		32	+53	9
1887	29	31	+54½	10
1878	July 30	32	+53	12
1898		23	+53	SS
1900		30	+52	F
1900		31	+54	10
1899	July 29–Aug. 2	34	+54	8
1878	July 31	32	+53	20
1877		35	+54	11
1878	Aug. 1	32	+54	10
1887		36	+56	4
1897	1–2	36	+56	13
1886	2	33	+55	12
1888		35	+54	14
1881		39	+55	14
1877	3	39	+55	7
1886	4	37	+57	12
1877		41	+56	6

			α	δ	↙'s
1893	Aug.	5	39	+55	4
1888			42	+57	11
1896		6	42	+56	7
1887			42	+55	5
1899			40	+55	6
1877		7	40	+56	7
1899			41	+58	10
1880			41	+55	14
1887			43	+56	5
1895			41	+57	5
1880		8	41	+55	23
1893			41	+56	12
1888			42	+57	20
1887			43	+56	5
1893		9	43	+57	20
1880			44	+55	71
1899			44	+57	26
1879			46	+58	38
1874		10	44	+58½	252
1876			43	+59	43
1877			43	+58	285
1878			42½	+54	106
			44	+59	
1880			45	+57	41
1882			43	+57	8
1884			44	+59	16
1886			44	+57	122
1887			42½	+57½	22
1893			45	+57	14
1895			45	+55	17
1896			45	+57	69
1899			44	+57	72
1901			44	+58	55
1880		11	48	+57	43
1882	Aug.	11	46	+57	45
1886			47	+57	15
1887			45	+57½	16
1895			44	+58	7
1899			46	+57	69
1901			45	+58	49
1898			46	+58	106
1880		12	48	+57	19
1877			50	+55	14
1899			48	+5	43
1893			48	+58	7
1896			46	+57	7
1880		13	49½	+57½	7
1888			52	+57	13
1885			51	+58	6
1899			49	+58	10
1893			48	+58	8
1899		14	50	+56	12
1893			49	+57	7
1887			53	+57	8
1901		15	51	+58	6
1901			56	+58	SS
1901			52	+53	F
1884–5		15–16	53	+59	5
1893		16	52	+57	4
1899			53	+57	7
1900			54	+58	5
1901			53	+58	5
1885–91		17	54	+60	5
1893–1901		18	55	+59	11
1884–1901		19	57	+59	5
1901		20	57	+58½	6
1901		21	61	+59	7
1900–1		22–3	59	+59	5

Radiant Points of Perseids determined by various Observers.

		α	δ	↙'s	
1900	July 19	15	+49	SS	A.S.H.
1897	22–7	23	+49	17	A.S.H.
1900	23	23	+51	5	W.E.B.
1900	July 23	20	+51	SS	A.S.H.
1900		27	+54	SS	A.S.H.
1897	23–4	24	+50	5	A.S.H.

		α	δ	↙'s	
1900	July 24	25° + 52½°	7	W.E.B.
1897	25	22 + 52	4	H.C.
1888	26	20 + 55	5	D.B.
1891	27	28 + 58½	7	D.B.
1898	29	31 + 54	5	E.R.B.
1897	30	37 + 53	4	H.C.
1900		30 + 54	4	E.M.A.
1900	July 30–Aug. 1	33 + 54½	4	J.H.B.
1897	July 30–Aug. 2	27 + 53	24	A.S.H.
1897	Aug. 1	33 + 56	4	E.R.B.
1899		30 + 54½	5	J.H.B.
1895	2	35 + 55	16	E.R.B.
1897	3	32½ + 57	6	W.E.B.
1901		35 + 56	...	E.M.A.
1895	3–4	43 + 57	6	W.H.M.
1895	4	38 + 54	5	E.R.B.
1891		39 + 57	11	D.B.
1893	5	39 + 54	4	E.R.B.
1896		37 + 57	10	W.H.M.
1897	2–8	36 + 55	17	A.S.H.
1894	6	38 + 56	15	E.R.B.
1894		45 + 57	8	W.H.M.
1894		45 + 57	15	H.C.
1895	7	39 + 53	11	E.R.B.
1895		40 + 56	7	H.C.
1900		39 + 54	5	J.H.B.
1888	8	42 + 57½	21	D.B.
1893		42 + 55	21	E.R.B.
1894		47 + 57	4	H.C.
1893	9	44 + 55	9	E.R.B.
1894		41¼ + 54½	...	C.D.P.
1894		42 + 56	17	E.R.B.
1893		43 + 57	15	D.B.
1895		43 + 57	23	H.C.
1896		40 + 58	22	W.H.M.
1897		42 + 56	21	A.S.H.
1897		51 + 57	19	A.S.H.
1897		45 + 57	17	H.C.
1897	Aug. 9	43½° + 57½°	71	W.E.B.
1898		42 + 55½	10	J.H.B.
1899		41 + 55½	8	J.H.B.
1899		44½ + 57	7	A.K.
1901		41 + 57	...	E.M.A.
1901		40 + 55	4	J.H.B.
1893	10	44 + 56	50	E.R.B.
1893		45 + 57	17	W.H.M.
1893		44 + 57½	100	H.C.
1894		46 + 55	...	C.D.P.
1894		42 + 56	49	E.R.B.
1894		45 + 51	15	H.J.T.
1896		46 + 57	11	J.A.H.
1896		43 + 58	20	E.R.B.
1896		47½ + 58	...	D.B.
1896		47 + 58	30	H.C.
1898		43 + 55½	16	J.H.B.
1898		43 + 59	11	H.C.
1898		45 + 55	...	T.E.R.P.
1898		43 + 53	...	H.J.T.
1899		43 + 56	12	J.H.B.
1899		45 + 57	29	A.K.
1899		45 + 58	54	W.E.B.
1899		45 + 56	84	E.M.A.
1901		43 + 56½	7	J.H.B.
1893	11	44½ + 57½	23	W.D.
1894		44 + 65	...	C.D.P.
1895		45 + 56	13	E.R.B.
1895		43 + 58	...	A.S.H.
1895		43½ + 58	72	H.C.
1896		45 + 55	43	E.R.B.
1898		45 + 58	40	W.E.B.
1898		45 + 56	13	J.H.B.
1898		49 + 58	13	H.C.
1898		46 + 58	...	T.E.R.P.
1898		46 + 56	29	H.J.T.
1898		45 + 58	30	E.R.B.
1899		45 + 57	18	J.H.B.
1899		45 + 57	8	W.E.B.

			α	δ	↙'s	
			°	°		
1899	Aug	11	46	+57	17	A.K.
1899			46½	+56	116	E.M.A.
1900			43	+56½	6	J.H.B.
1901			46½	+57	14	A.K.
1901			44½	+56½	9	J.H.B.
1893		12	44	+56	26	E.R.B.
1896			48	+57	6	E.R.B.
1896			48	+60	30	H.C.
1899			46	+56⅓	10	J.H.B.
1899			46	+57	6	E.M.A.
1899			46½	+58	7	A.K.
1899			48	+58	15	W.E.B.
1900			48	+58	12	A.K.
1901			47	+58	13	A.K.
1901			44	+57	...	E.M.A.
1888		13	51½	+56	17	D.B.
1895			51½	+56½	14	H.C.
1896			50	+59	10	E.R.B.
1899			48	+55	15	E.M.A.
1899			49	+57	5	A.K.
1899			49	+58	10	E.M.A.
1899		13–14	49	+58	8	A.K.
1888		14	55	+59½	5	D.B.

			α	δ	↙'s	
			°	°		
1891	Aug.	14	56	+58½	8	D.B.
1893			49	+55	10	E.R.B.
1893			54	+59	...	H.C.
1895			51	+58	6	E.R.B.
1896			51	+59	24	E.R.B.
1899			50	+58	5	W.E.B.
1900			50	+56	5	E.M.A.
1891		15	58½	+59½	6	D.B.
1893			51½	+59	...	E.R.B.
1893			55	+57	5	H.C.
1896			50	+58	8	W.H.M.
1901			51	+58	4	A.K.
1901			48	+58	5	J.H.B.
1901			53	+58	...	E.M.A.
1901			54	+53	F	A.S.H.
1901			58	+58	SS	A.S.H.
1893		17	58	+62	7	E.R.B.
1893		18	54	+62	...	E.R.B.
1893			51	+56	11	H.C.
1901		19	53	+58	...	E.M.A.
1893		21	55	+57	3	W.H.M.
1893			55	+65	6	

Mean Radiant Points of Perseids.

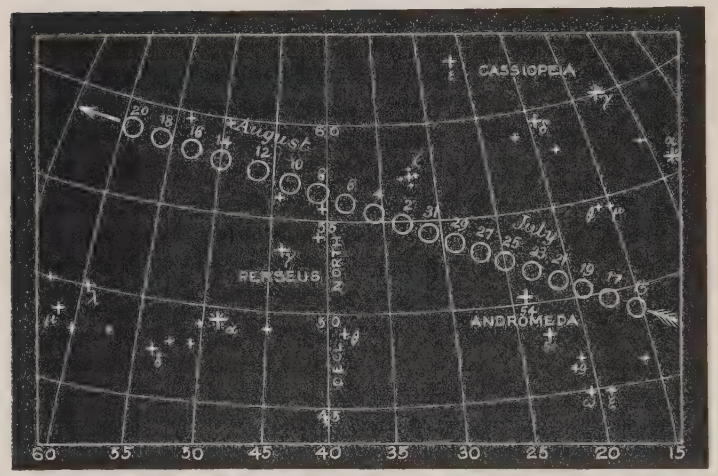
	W.F.D. α	W.F.D. δ	W.F.D. Radiants.	Other Observers. α	Other Observers. δ	Other Observers. Radiants.	Mean of all. α	Mean of all. δ	Mean of all. Radiants.
	°	°		°	°		°	°	
July 8–13	11·0	+48·0	1	...	...	...	11·0	+48·0	1
18	17·0	+50·0	1	...	...	...	17·0	+50·0	1
19	18·0	+50·5	2	15·0	+49·0	1	17·0	+50·0	3
20	...	...	...	...	...	...	...	...	...
21	23·0	+52·0	1	...	...	...	23·0	+52·0	1
22	25·0	+52·0	1	...	...	...	25·0	+52·0	1
23	24·5	+52·0	2	23·3	+52·0	3	23·8	+52·0	5
24	23·0	+52·0	1	25·0	+52·5	1	24·0	+52·2	2
25	22·0	+52·0	1	22·0	+52·0	1	22·0	+52·0	2
26	30·0	+53·0	1	20·0	+55·0	1	25·0	+54·0	2
27	29·0	+54·0	1	28·0	+58·5	1	28·5	+56·3	2
28	30·2	+54·0	4	...	...	...	30·2	+54·0	4
29	31·0	+54·5	1	31·0	+54·0	1	31·0	+54·2	2

		W.F.D. α δ	Radiants.	Other Observers. α δ	Radiants.	Mean of all. α δ	Radiants.
		° °		° °		° °	
July	30	29·0 + 53·0	4	33·5 + 53·5	2	30·5 + 53·2	6
	31	33·7 + 53·7	3	33·0 + 54·5	1	33·5 + 53·9	4
Aug.	1	34·0 + 55·0	2	31·5 + 55·3	2	32·8 + 55·1	4
	2	35·7 + 54·7	3	35·0 + 55·0	1	35·5 + 54·7	4
	3	39·0 + 55·0	1	33·7 + 56·5	2	35·5 + 56·0	3
	4	39·0 + 56·5	2	38·5 + 55·5	2	38·8 + 56·0	4
	5	40·5 + 56·0	2	37·3 + 55·3	3	38·6 + 55·6	5
	6	41·3 + 55·3	3	42·7 + 56·7	3	42·0 + 56·0	6
	7	41·2 + 56·4	5	39·3 + 54·3	3	40·5 + 55·6	8
	8	41·7 + 56·0	4	43·7 + 56·5	3	42·6 + 56·2	7
	9	44·2 + 56·7	4	42·9 + 56·3	15	43·2 + 56·4	19
	10	43·9 + 57·3	15	44·4 + 56·3	19	44·2 + 56·8	34
	11	45·9 + 57·4	8	45·1 + 57·4	19	45·3 + 57·4	27
	12	48·0 + 56·8	5	46·5 + 57·5	10	47·0 + 57·3	15
	13	49·9 + 57·7	5	49·8 + 56·9	6	49·9 + 57·3	11
	14	50·7 + 56·7	3	52·0 + 57·9	8	51·6 + 57·5	11
	15	53·0 + 56·3	3	53·2 + 57·6	9	53·2 + 57·3	12
	16	53·0 + 57·5	4	... ...	...	53·0 + 57·5	4
	17	54·0 + 60·0	1	58·0 + 62·0	1	56·0 + 61·0	2
	18	55·0 + 59·0	1	52·5 + 59·0	2	53·3 + 59·0	3
	19	57·0 + 59·0	1	53·0 + 58·0	1	55·0 + 58·5	2
	20	57·0 + 58·5	1	... ...	...	57·0 + 58·5	1
	21	61·0 + 59·0	1	55·0 + 61·0	2	57·0 + 60·3	3
	22–3	59·0 + 59·0	1	... ...	...	59·0 + 59·0	1
			99		123		222

It will be seen from the mean positions of the radiant that the R.A. does not exhibit a regular diurnal increase, but that some marked irregularities are apparent. These are obviously due to errors of observation, which in certain cases have been large, and which, even in the most accurate results, have not been wholly eliminated. If the mean values for the radiant from all the observations are grouped into five-day periods the increase in the R.A. and N. Dec. becomes well defined, as follows :—

Period.	Mean Place of Radiant. α δ	Number of Radiants.
	° °	
July 18–22	20·5 + 51·0	6
23–27	24·7 + 53·3	13
28–Aug. 1	31·6 + 54·1	20
Aug. 2–6	38·1 + 55·7	22

Period.	Mean Place of Radiant. α	δ	Number of Radiants.
	°	°	
Aug. –11	43·2	+ 56·5	95
12–16	50·9	+ 57·4	53
–22	56·2	+ 59·4	12



Positions of the Perseid Radiant Point, July 15 to August 20.

From the whole of the observations I have drawn up the following ephemeris, but the figures are not intended to simply represent the curve deduced from them, certain corrections having been applied. The year 1900 not being Leap Year, and nearly all the materials having accumulated before that year, the result is that the position of the radiant will be about 1° less in R.A. in the immediate future than on the same date before 1900. In fact, the maximum displays of the shower will occur a day later, and be witnessed either on August 11 or 12. I have allowed for these effects, and also for the circumstance that my own observations and a certain proportion of the others required a small correction for precession. A few of the observed radiants included in the tables are undoubtedly erroneous, from their discordance with others of contemporary date, and all such positions should be excluded in attempts to derive reliable places for the shower.

It is to be hoped that observers will carefully test the degree of accuracy of the ephemeris, either by photographs of meteor trails or by very exact eye-observations, in future years. I think it quite possible that the radiant should be placed a little farther north, particularly at about the period of the maximum, for the presence of the stars γ and η *Persei* just south of the radiant must probably have exercised a slight influence in leading

observers to place the centre too far south. It is often found that when a bright or fairly conspicuous star is situated near a radiant the latter is apt to be assigned nearer to the star than the truth requires. The ephemeris gives the R.A. of the radiant as less than that indicated in the similar table published in *Memoirs*, vol. liii., p. 210; but this is to be chiefly ascribed to the alteration rendered necessary by the absence of leap year in 1900, and moreover the present ephemeris has been independently formed from more extensive materials than could possibly be employed in the previous case:

Ephemeris of the Perseid Radiant Point.

	α	δ		α	δ
	°	°		°	°
July 15	15·3	+48·9	Aug. 3	35·1	+55·3
16	16·2	+49·3	4	36·4	+55·5
17	17·1	+49·7	5	37·6	+55·7
18	18·0	+50·1	6	38·9	+56·0
19	18·9	+50·5	7	40·2	+56·2
20	19·8	+50·8	8	41·5	+56·5
21	20·8	+51·1	9	42·9	+56·7
22	21·8	+51·5	10	44·3	+56·9
23	22·8	+51·8	11	45·7	+57·1
24	23·8	+52·2	12	47·1	+57·3
25	24·9	+52·5	13	48·5	+57·5
26	26·0	+52·8	14	50·0	+57·7
27	27·1	+53·2	15	51·4	+57·8
28	28·2	+53·5	16	52·9	+58·0
29	29·3	+53·8	17	54·4	+58·2
30	30·5	+54·1	18	55·9	+58·4
31	31·6	+54·4	19	57·4	+58·5
Aug. 1	32·7	+54·7	20	58·9	+58·7
2	33·9	+55·0			

Probably the display commences in a very feeble form before July 15, and is continued to a later date than August 20. In the third week of July the shower is, however, very liable to be confused with a radiant of swift, streak-leaving meteors directed from near γ *Andromedæ* ($24°+43°$); and in the third week of August it becomes apparently blended with a shower of *Camelopardids* ($60°+59°$).

Bishopston, Bristol: 1901 *November* 10.

Note on a Large Fireball. By W. F. Denning.

At $5^h\ 36^m$, soon after dark on the very clear frosty evening of December 4 last, a fireball of exceptional brilliancy was observed from various parts of the country. It gave a flash of dazzling intensity, illuminating the English Channel and South of England with a light stronger than that of the full Moon. The fireball had a bluish-green head, and along the more luminous section of its flight it projected a train or streak of orange-red material, which remained visible to the eye from a few seconds to five minutes according to the various estimations made by different persons.

The position of the train amongst the stars was carefully noted by several observers. Admiral Maclear at Chiddingfold, Surrey, found it to extend from $290\frac{1}{2}° + 11\frac{1}{2}°$ to $295\frac{1}{2}° + 5\frac{1}{2}°$, and Mr. G. F. Oldham, of Tunbridge Wells, Kent, says it was 7° or 8° long and placed midway between o *Herculis* and χ *Aquilæ*, and in a straight line with these stars and the planet *Venus*. The Rev. W. F. A. Ellison, of Dublin, saw the fireball as it flashed out in *Cetus*, low in the S.E., and the place of the lingering train was from $7° - 10°$ to $16° - 16°$. From these and some additional descriptions which I have compared the real path appears to have been as follows :

Height at beginning	...	91 miles over English Channel, 11 miles S. of Bridport, Dorset.
Height at ending ...	...	50 miles over English Channel, 15 miles S. of Needles, Isle of Wight.
Length of path ...	...	64 miles.
Approximate velocity	...	21 miles per second.
Earth point ...	...	37 miles S. of Brighton.
Height of streak ...	...	72 to 55 miles.
Length of streak ...	...	26 miles.
Radiant point ...	...	$263° + 36°$.

These results approximately represent a portion of the course. The whole of the luminous flight of this brilliant *Herculid* fireball may quite possibly have extended further, both at the beginning and end, but precise limits cannot be assigned, many of the observations being indefinite and some of them contradictory on this point.

Bishopston, Bristol : 1901 *December* 10.

Observation of the Leonid Meteors of 1901, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

On the nights of November 14–15 and November 15–16 watch for meteors was maintained by four observers from midnight to 5 A.M., with the following results :—

Date. 1901.	Length of Watch.	Total Number of Meteors.	Number of Leonids.	Number of Leonids per Hour.
November 14–15	5 hours	66	46	9·2
„ 15–16	5 „	43	43	8·6

The night of November 13–14 was overcast and rainy, November 14–15 was cloudless and bright, and November 15–16 was partially foggy and cloudy. The number of Leonids observed each year since 1887 is given in the *Monthly Notices*, vol. lx., p. 163. Reference to this table shows that a much larger number of meteors was observed this year, though it should be remembered that the weather was rather more favourable this year than in most of the preceding years. These observations afford some evidence that this year the Earth passed through part of the meteor swarm denser than the average, and probably denser than in any of the years 1896 to 1900.

Royal Observatory, Greenwich:
1901 *December* 19.

The Leonids, 1901. *Observations made at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

During the night of November 13 the sky was occasionally watched for a possible shower of *Leonids*, but few meteors were seen.

On November 15 from 12^h to 15^h G.M.T. the sky was generally clear, but high driving fog passed across at times. Mr. McClellan, who watched at frequent intervals, saw only two meteors, viz. :—

G.M.T.
h m
14 40 1st magnitude; Leonid with train from μ Leonis towards 38 Lyncis.

14 42 Sporadic.

A special watch for meteors was commenced on the night of November 14, just before 13^h G.M.T., by Mr. Robinson. Except during a short break ($15^h\ 11^m$ to $15^h\ 23^m$ G.M.T.) the watch was continuous until 18^h G.M.T. The observer remarks :—

At first the constellation of *Leo* was only dimly visible in a low mist, which, however, became less dense later on. The sky was cloudless throughout, and stars to the 5th or 6th magnitude could be easily seen, except for small altitudes. About 17^h G.M.T., and a little earlier, a long band of diffused light about 10° in width was observed stretching from the eastern horizon towards and slightly beyond the six stars forming the "Sickle." The phenomenon—probably that of the zodiacal light—became more conspicuous later on, or just before dawn. Its position then lay along the ecliptic, enveloping *Spica* in E.S.E., across the constellations of *Virgo* and *Leo*, the brightest and broadest portion being over the horizon.

The *Leonids* presented the characteristic features observed in former years, being swift, and generally leaving luminous trails, visible for two or three seconds. The approximate G.M.T. for each meteor was recorded, and notes of magnitude, direction, velocity, and trails of the more important were taken. When the observer had fully identified the brighter stars in the neighbourhood of *Leo*, several of the more luminous tracks were charted. For this purpose a wand, held and adjusted across the trail or streak, enabled a reliable observation to be made of the direction of the flight of the meteor. Seven observed in this way give a radiant of small area near

R.A. $9^h\ 55^m\ 50^s$ or 148° 58′; Decl. +22° 47′. Epoch 1900.

Almost invariably the paths of the other *Leonids* when produced backwards along the wand crossed the same point within the "Sickle." A number of the brighter meteors started at a great distance (about 30°) from the radiant.

Other radiants were apparently active, but meteors from these were regarded as of secondary importance, and their paths were secured with only rough approximation.

A marked peculiarity was the intermittent frequency of the *Leonids*, several long quiescent intervals being followed by active miniature showers. This feature was also noticed here in 1898 or 1899.

The following notes of meteors were taken :—

No.	G.M.T. h	m	
1	12	51	1st mag.; passed between β and γ Ursæ Maj.; trail; Leonid.
2	12	58	Above Sirius; no trail; rapid.
3 6	13	0 to 13 17	In this interval 4 meteors counted, two of which possibly Leonids. The last a short bright streak above Leo.
7	13	20	Leo towards zenith; swift; no streak.

No.	G.M.T. h m	
8	13 24	S.E. Sickle; streak.
9	13 25	Leo towards zenith; very swift.
10	13 26	Short; in Gemini.
11	13 30	Short; possibly Leonid.
12	13 30	Near Pollux, below Pleiades; long bright trail.
13	13 33	1st mag.; track recorded on chart (A).
14	13 38	N. and N.W.; swift; 4th mag.
15	13 50	Short; low down N.E.; small.
16	13 51	From zenith; sporadic.
17	13 55	Ursæ Maj. to zenith; 3rd mag.
18	14 0	Above Leo; sporadic; 4th mag.
19	14 4	Through Gemini; streak; 3rd mag.
20	14 4	Below Sirius; swift; streak; 1st mag.
21	14 10	Sickle through zenith; long streak; 1st mag.
22	14 17	Near Sirius; sporadic; short; 4th mag.
23	14 19	Between ζ and μ Leonis; short; 4th mag.
24	14 21	Below Sickle; sporadic.
25	14 21	Above Sickle; sporadic.
26	14 24	Streak; 3rd mag.; path recorded (B) on chart.
27	14 30	N.E.
28	14 36	Through pointers of Ursæ Maj. to below pole; streak; bright; swift.
29	14 38	Through or near Aldebaran.
30	14 39	Passed between β and γ Ursæ Maj.; Leonid.
31	14 46	Ursæ Maj., low; doubtful Leonid.
32	14 49	Slow sporadic from between δ and β Leonis to below Regulus; streak; 4th mag.
33	14 50	Zenith towards Coma Berenices; 3rd mag.
34	14 54	Castor and Pollux to Sickle; sporadic.
35	14 55	Præsepe to γ Leonis; sporadic.
36	14 58	Sickle to between θ and α Hydræ.
37	14 59	Bright, from zenith.
38	15 2	Near δ Leonis, from Sickle.
39	15 6	Just above λ Ursæ Maj. to δ Ursæ Min. Direction same as A in chart.
	15 11 to 15 24	Break in watch.
40	15 26	Around Leo; not Leonids.
41	15 26½	
42	15 27	

No.	G.M.T. h m	
43	15 31	Canes Venat., through Coma Berenices ; sporadic.
44	15 36	Leonid ; through α Canum Venat., below η Ursæ Maj. ; streak.
45	15 38	Leonid; slightly above θ Hydræ, to Argo ; streak.
46	15 41	From midway between Regulus and θ Hydræ, to east of Argo ; streak.
47	15 43	Passed between β and γ Ursæ Maj. ; Leonid.
48	15 43	Towards Cassiopeia ; swift ; 1st mag.
49	15 45	λ and μ Ursæ Maj. ; Leonid ; streak.
50	15 45	Below Leo ; Leonid ; streak.
51	15 47	Coma Berenices and β Leonis ; streak.
52	15 (49)	Sporadic ; west of Leo.
53	15 50	Leonid ; between Regulus and o Leonis.
54	15 54	Towards S.E., from the western sky.
55	15 57	Leo to east of α Hydræ ; very swift ; no trail.
56	16 0	Bright ; streak ; path recorded on chart (C).
57	16 0½	Probably Leonid.
58	16 4	N.E. ; swift.
59	16 7	Through Procyon ; bright streak ; Leonid.
60	16 7	Leonid ; faint.
61	16 9	Sporadic.
62	16 10	Through ι and κ Ursæ Maj. ; bright.
63	16 10	ENE^{ly} direction ; bright.
64	16 21	NW^{ly} direction ; streak.
65	16 21	Streak.
66	16 21	Streak.
67	16 22	Streak ; towards η Ursæ Majoris from Radiant.
68	16 22	Streak ; towards Ursa Major from Radiant.
69	16 23	Towards Arcturus.
70	16 26	Radiant to α Ursæ Maj. ; streak.
71	16 27½	1st mag. ; sporadic ; Ursa Maj. ; N.E. of Arcturus ; sinuous.
72	16 29	Leonid ; streak, towards Castor.
73	16 31	Sporadic.
74	16 37	Streak ; sporadic ; Præsepe through ϵ Leonis.
75, 76	16 42	Two short Leonids, the first near γ Leonis, the second below the Sickle.
77, 78	16 46	Two from zenith to east ; sporadic.
79, 80	16 49	Two doubtful Leonids.
81	16 56	Streak ; Radiant to east.

No.	G.M.T. h m	
82	16 56	Streak; Radiant to east.
83	16 56	Streak; charted (D).
84	17 0	Leonid; towards δ or β Leonis.
85	17 2	Low E.S.E.; possibly Leonid.
86	17 5	No streak; in Leo.
87	17 5	No streak; in Leo.
88	17 6	Short; Leo; no streak.
89	17 12	Short; in Leo.
90	17 14	East of Regulus; eastwards.
91	17 15	Below Sickle; sporadic.
92	17 19	Leonid; Virgo.
93	17 20	Sporadic; Hydra.
94	17 21	Streak.
95	17 21	Bright; rapid; low down.
96	17 22	Streak from Hydra; sporadic.
97	17 23	Leonid; near Regulus; streak.
98	17 29	Streak; Leonid; between Hydra and Præsepe.
99	17 33	Leonid; below Arcturus.
100	17 34	Bright streak; charted (E).
101	17 44	To zenith.
102	17 45	To east.
103	17 45	Streak to N.E.
104	17 53	Streak; Leonid.
105	17 53	Streak; Leonid; charted (F).
106	17 59½	Bright streak; charted (G).
	18 0	Watch relinquished; twilight increasing.

The positions of the seven charted paths were as follows :

Epoch 1880.

		R.A. h m	Dec. ° ′		R.A. h m	Dec. ° ′
(A)	From	9 59	+32 30	To	10 11	+50 0
(B)	„	9 6	+13 0	„	8 26	+6 0
(C)	„	10 55	+30 15	„	12 0	+39 30
(D)	„	9 53	+17 0	„	9 53	+5 0
(E)	„	9 10	+16 45	„	8 0	+7 30
(F)	„	9 37	+18 0	„	9 0	+5 0
(G)	„	10 24	+23 0	„	12 1	+20 0

Radcliffe Observatory, Oxford:
1901 *December* 11.

Apparent Paucity of the Leonid Stream.
By the Rev. S. J. Johnson.

The morning of November 14 was densely clouded; that of the 15th clear and frosty, giving opportunity for observation, especially as the Moon was absent. A little watching soon showed that the shower, though existing, was very feeble at the time and far inferior to that of the *Perseids* last August. It was about equal in intensity to that which I witnessed on the morning of 1896 November 14. From 2^h to 2^h 45^m (morn.) on the 15th I observed three *Leonids*, the largest being at 2^h $42\frac{1}{2}^m$, about 10° beneath *Regulus*; also one non-*Leonid* across η.

From 4^h to 5^h (morn.) five *Leonids*, two of which equal bright first magnitude stars, one at 4^h7^m, just beneath 46 *Leon. Min.*, greenish. From about 161°+34° to 163°+36°; the other at 4^h 24^m, started about 3° left of *Arcturus*. From 215°+21° to 220°+18°.

On the morning of the 16th the radiant was slightly more active. Still, the Earth could only have been passing through outlying portions of the shower. From 4^h 55^m to 6^h A.M. I noticed nine *Leonids*, all within the first thirty-five minutes.

At 4^h $55\frac{3}{4}^m$ (morn.) nearly equal *Jupiter*, green train. Just beneath β *Leonis*. 173°+16° to 180°+13°.

At 5^h $1\frac{1}{4}^m$ magnitude 1 train. From a point 7° above δ *Leonis* going towards 12 *Coma Beren.* 168°+27° to 180°+28°.

At 5^h $23\frac{3}{4}^m$ equal *Jupiter*. Between ϵ *Virginis* and *Arcturus*. 197°+21° to 207°+11°.

All the *Leonids* seen had momentary trains.

Place of observation, window facing eastern heavens with several obstructions.

Melplash Vicarage, Bridport:
Nov. 30.

The Leonids, 1901. By F. W. Henkel, B.A.

The weather having been better on the whole than is usual at this time of the year at Markree, there was an opportunity of observing any display of meteors should it occur, but nothing of any consequence was seen here on the nights of November 15 and 16, which were clear for the most part. Being myself in England at the time, in the neighbourhood of Epping Forest, I made a watch from about 11 P.M. till towards daylight on the night of the 15th–16th, but saw nothing worthy of remark. The following night (Saturday) there was a dense fog, which prevented anything being seen of the sky at all. A gentleman whose occupation involves his being in London most part of the night, and who

watched from the neighbourhood of Dalston, told me that he saw no meteors at all.

It is evident from the reports to hand that there has not been any display this year of any consequence, though a few observers have been able to see a small number of meteors. It seems fairly certain that we are not likely to witness in this decade anything at all approaching the wonderful displays of 1833 and 1866, which have caused such an interest to attach itself to this swarm, but perhaps those of us who survive for another thirty years may be more fortunate.

Markree Observatory: 1901 *December* 10.